United States
Department
of Agriculture

**Agricultural
Research
Service**

ARS–122

April 1994

Stone Fruit Tree Decline, Sixth Workshop Proceedings

New Insights & Alternative Management Strategies

Fort Valley, Georgia
October 26–28, 1992

United States
Department
of Agriculture

**Agricultural
Research
Service**

ARS–122

April 1994

Stone Fruit Tree Decline, Sixth Workshop Proceedings

New Insights & Alternative Management Strategies

Fort Valley, Georgia
October 26–28, 1992

Andrew P. Nyczepir, Paul F. Bertrand,
and Thomas G. Beckman, Editors

Nyczepir, Andrew P., Paul F. Bertrand, and Thomas G. Beckman, eds. 1994. Stone Fruit Tree Decline, Sixth Workshop Proceedings. U.S. Department of Agriculture, Agricultural Research Service, ARS–122, 154 pp.

Keywords: Almond, biological control, cherry, cultivars, disease, economics, fungus, insects, nematodes, nonchemical control, peach, peach tree short life, pesticides, plum, *Prunus*, resistance, rootstock.

Note to libraries: At this issuance date, the fifth workshop proceedings on stone fruit tree decline was not yet published; it will be published later.

While supplies last, single copies of this publication may be obtained at no cost from USDA-ARS, Southeastern Fruit and Tree Nut Research Laboratory, 111 Dunbar Road, Byron, GA 31008.

Copies of this publication may be purchased from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

Acknowledgements

The authors extend their gratitude to the secretaries who prepared manuscripts for this proceedings. Special recognition is due Teri Sheriff who worked many days to edit, proofread, and assemble all the manuscripts. Sincere appreciation is extended to Floyd Hendrix for his assistance in planning the workshop and to everyone else who helped with the tours and other workshop functions.

Issued April 1994

Contents

Diseases

Entomology

PREFACE

Difficulties of maintaining longevity and productivity of stone fruit trees have been the motivation for six workshops on this subject. The first Stone Fruit Decline Workshop was held in East Lansing, Michigan (1982) to discuss stone fruit decline problems and initiate communication lines for cooperative research. The second workshop was held in Kearneysville, West Virginia (1984) where the meeting theme dealt with biological agents and their interaction with the host tree. In 1986, the third workshop was held in Clemson, South Carolina to identify and discuss various stress factors in the orchard environment associated with stone fruit decline. The fourth workshop assembled in Parlier, California (1988) to discuss and present papers on tree fruit decline problems dealing with such topics as viruses, nematodes, fungi, environmental factors/physiology changes, and breeding and resistance. In 1990 the fifth workshop was held in Biglerville, Pennsylvania where the theme of this meeting centered around integrated crop management for the prevention of stone fruit decline.

The sixth workshop assembled at the C.W. Pettigrew Farm & Community Life Center in Fort Valley, Georgia (October 26-28, 1992), where topics of discussion concentrated on new insights and management strategies of pathogens, pests, and physical factors associated with stone fruit decline. Present at the meeting were stone fruit researchers and extension personnel from Michigan State University, The University of Georgia, North Carolina State University, Clemson University, USDA-ARS (GA, WV, and CA), Fort Valley State College, University of California, Auburn University, Pennsylvania State University, Rutgers University, and Texas A&M University. Formal presentations and overviews were given and discussed. Valuable information was exchanged at this meeting (as in previous Stone Fruit Decline Workshops) and most of the papers that were presented are contained in this Proceedings. On October 28, the participants were given a tour of USDA-ARS, Southeastern Fruit and Tree Nut Research Laboratory and the Fort Valley State College Fruit and Research and Goat Centers.

I wish to thank all of the participants, session moderators, and all of the behind-the-scenes people who made this Stone Fruit Decline Workshop the success it was.

Andrew P. Nyczepir, Editor
USDA-ARS
Southeastern Fruit and Tree Nut
Research Laboratory
Byron, Georgia

Participants in the Sixth Stone Fruit Decline Workshop are, front row, from left: A. Nyczepir, G. Philley, R. Lane, W. Westcott, M. Longstroth, J. Springer, J. Flore, B. Ferree, W. Miller, B. Tang, E. Zehr, J. Payne; back row, from left: D. Okie, D. Evert, L. Pusey, W. Skroch, E. Sikora, F. Hendrix, B. Olien, T. Beckman, P. Bertrand, H. Melakeberhan, G. Reighard, J. Frecon, W. Asai, D. Teulon, L. Campbell, C. Ledbetter, A. Latham, M. Glenn, and M. McKenry.

In attendance of the meeting but not in photo: U.L. Yadava, C.E. Yonce, D.L. Horton, and J.R. McVay.

RESEARCH ON STONE FRUIT AT MICHIGAN STATE UNIVERSITY

J.A. Flore[1]

Stone fruit are an important part of Michigan's fruit industry. Sweet and tart cherries, peaches and plums account for approximately 60,000 acres, and have an estimated farm value of $52,000,000, and a total value of $158,000,000 after processing and packing. Michigan ranks 1st nationally in the production of red tart cherries, 3rd for sweet cherries, and fourth for fresh market peaches. Our climate and soils and close proximity to major markets places Michigan in a good position to produce stone fruit. Stone fruit are not without their problems however. They tend to be cold tender, bloom earlier than pome fruit, are more vulnerable to early spring frosts, and are susceptible to a wide range of insects and diseases, consequently cropping is more variable, and tree life is shorter.

Michigan State University has always had a strong commitment to research and extension on stone fruit. Currently, the Michigan Agricultural Experiment Station funds over 22 scientists from 7 different departments on 30 different projects (AES Annual Report, 1991) that are directly related to stone fruit. In addition to AES and CES, industry, federal and state grants help to round out the funding for these crops. One of the largest components of support for research has come from the Stone Fruit Decline grant funded since 1985 from the USDA-ARS special grants.

BACKGROUND LEADING UP TO THE STUDY

Stone fruit decline in Michigan and in other areas of the country (California, South Carolina, Georgia, and Pennsylvania) is well documented. In each area of the country it results from a different set of problems characteristic of that region. At the time of the initiation of the grant in Michigan(1985), peach acreage and tree numbers had decreased 52 and 53% respectively since 1973, and there was a sharp decrease in the average tree age for other stone fruit crops. In addition, it was noted that annual production was greatly affected by spring frost, which can best be illustrated by the degree of crop fluctuation in tart cherry. Tart cherry yield has varied from 87 to 260 million pounds at prices to the grower of $6 to $49.1 per cwt. since 1979. This fluctuation in yield was also substantiated in a recent survey of fruit growers that indicated that they had less than 25% of a crop on tart cherries 16.1% of the time and only 8.1% of the time for apples. This fluctuation in yield and price decreases market stability and affects farm profitability.

The Michigan plum industry has also declined drastically over the past 15 years. The 1986 Michigan Orchard and Vineyard Survey indicated that the state had 540 plum growers with 415,000 trees on 3,900 acres. This was a decrease of 102,503 trees and 1,517 acres since 1978.

In 1982, Dr. Ed Klos, while Chairperson, Department of Botany and Plant Pathology, MSU in conjunction with the USDA, organized the 1st Stone Fruit Decline conference, which was held at MSU in 1982. Research and extension personnel from all over the U.S. convened to review the decline situation, and they identified several areas that needed attention. Since then this meeting has been held in a different area of the country every two years. The Michigan grant was first funded in 1985, and has funded more than 15 different AES Scientists, and more than 30 different graduate students and post-doctoral students in 5 different departments on campus.

The initial goal of this project was to accurately identify the cause of stone fruit decline in each of the four crops, peach, sweet cherry, sour cherry and plum, and to develop control strategies and management recommendations to minimize the effect of these problems on tree decline. Both short and long term research have focused on the elimination or control of factors which are contributing most to the decline problem. Results from the first study indicated that the major problems for each crop are as follows: Peach (winter injury, *Cytospora* canker, X-disease); sour cherry (spring frost,

[1]Department of Horticulture, Michigan State University, East Lansing, MI 48824

root related problems, mechanical harvest damage, borers, and virus diseases); sweet cherry (mechanical harvest damage, winter hardiness, and bacterial canker); and plum (cold injury, poor scion/rootstock compatibility, and virus).

SPECIFIC RECOMMENDATIONS TO GROWERS AND OTHER SIGNIFICANT ACCOMPLISHMENTS

I. **Cold hardiness.** Cultivar and rootstock influence mid-winter hardiness and the acclimation and deacclimation process. Rootstock should be chosen with the site in mind. If deep winter hardiness is of most concern, then 'Siberian C' would be the stock of choice; however, if acclimation is not important then 'Halford' or Bailey', or one of several other rootstocks would be the rootstock of choice. Future articles will focus on this topic.

II. **Root related problems.** The greatest single problem contributing to sour cherry decline is poor soil structure, which results in 'wet feet', anoxia, and death of the tree. To minimize this effect, growers should plant only in well drained soils. If that is not possible they should plant on raised beds (at least 12 inches in height). Mazzard rootstock should be chosen over Mahaleb (the standard rootstock used in the industry), because it is more resistant to wet feet, and Phytopthora root and crown rot. The velocity permeameter was the most reliable and expedient means to determine soil physical limitations. Armillaria was verified in 35 orchards in 1985, and 1986, on sandy soils between New Era and areas north of Traverse City. No cure has been found for this disease. Of 19 rootstocks tested Mazzard has been the most resistant to Armillaria and to wet feet.

III. **Cytospora canker.** At present no commercial recommendations can be made, however significant progress has been made in one area. Genetic differences for Leucostoma tolerance has been found in peach. This finding, shows promise for the introduction of canker tolerance into breeding programs.

IV. **Harvest systems.** A new pad system was developed for young trees. If this system is used properly, less than 1% damage can be expected. When growers used our recommendations (depends on equipment, and pad design), trunk damage was reduced significantly. A new shaker system has been designed and tested, and could be made ready for commercial application. It provides independent control of frequency, amplitude, and direction of shake.

V. **Borer control.** In cooperation with Dr. Roeloffs (Cornell), we successfully formulated a pheromone for the American plum borer (a pest on cherry). Using this trap as a tool to time sprays, chemical controls have virtually eliminated this insect as a problem.

VI. **Virus/nematode interactions.** Although no recommendations can yet be made to growers, we have found that Tomato ringspot virus can be spread by dagger nematodes, which feed on roots of dandelions and other orchard weeds as well as tree roots. If the virus is in the ground cover, it may be spread by the nematode. A laboratory test called ELISA (enzyme-linked immunosorbant assay) has been developed to detect the virus. Of trees with decline symptoms in cherry, 25% had the virus, compared to about 9% of trees in non-decline orchards.

VII. **X-disease.** cDNA probes against X-disease have been developed and evaluated. They can now be used to detect the disease in the carrier (leaf hoppers), the commercial peach or cherry planting, and possible alternative hosts. This tool may provide the method by which control of X-disease can be found.

VIII. **Cultural systems.** Peach. Accelerated production of peach seems quite feasible. Trees spaced 15' x 10' and trained to a central leader, yielded in excess of 350 bu/A in the 3rd year and 500+ in the 5th year, compared to 106 and 275 bu/A for conventional plantings. Plum. The cultivars Eldorado, Friar, and Laroda all produced well in Northern Michigan. Empress and Wickson are excellent late season plums, and Ozark Premier and Superior produce well in NW Michigan and have high quality fruits which could ship well if harvested at the proper time.

CURRENT RESEARCH AND ACCOMPLISHMENTS

Based on these results, and the difficult situation that the Michigan sweet cherry industry was in concerning tree decline, we have emphasized problems related to sweet cherry in the current grant. In 1988, Michigan ranked third in the U.S. in sweet cherry production, producing 56,000,000 lbs of fruit or 15% of the U.S. on 810,000 trees covering 9,400 acres. The value of the Michigan crop was $18,395,000, with an average cash receipt of $32.85/cwt. This is down from 980,000 trees and a yield of 75,000,000 lbs in 1973-75. In many cases the problems investigated cross several crops, and control in one will work for another. We have also chosen to concentrate on specific problems which relate to other crops. Major objectives of the current grant and principal investigators are as follows:

I. **Preplant Decisions (R. Perry, J. Flore, D. Ramsdell, G. Bird)**

A. Sweet cherry site selection and orchard establishment. An economic feasibility model for the production of sweet cherries was developed to determine if covering trees to protect from rain that cracks fruit could be profitable. At $10,000/acre for covers, $1.00/lb price, and 12,800 lbs/acre by the 7th year, the modelpredicted profitability by year 8. A prototype shelter was tested at two different sites in Michigan.

B. **New plum selections, rootstock combinations, and Tomato Ringspot Virus (TmRSV) susceptibility studies to correct plum decline problems.** Nearly 200 European, Janpanese, and Japanese American hybrid selections are currently being evaluated at the Northwest Station. Of the over 200 selections currently under study, approximately ten are superior fresh market types which mature over ten or more weeks; i.e., mid July through September. Only one selection, NY 58.900.12 is superior to currently available cultivars for canning purposes. A dozen superior fresh market European and Japanese types were test marketed in 1991 to determine suitability for packing, shipping, and marketing.

The plum rootstocks GF-8-1, GF-655-2, Damas 1869, St Julian A, Brompton, Myrobalan B, Marianna 4001, and Marianna 2624 were planted in 1991. Our most promising selections were grafted to these stocks and will be evaluated in the future.

This work has documented the severe negative effect of TmRSV and prunus necrotic ringspot virus on growth and yield of stonefruit. Growers are now warned that they should prevent TmRSV. This can be done at preplant time by eradicating the dagger nematode vector and planting clean stock.

Our survey of 21 plum orchards showed that all 21 plum orchards had trees infected with the virus and the percent of infected trees ranged from 4 to

82%. This virus not only reduced yield, but resulted in death to all of the 'Stanley'/Myrobalan 29C trees which comprise 98% of Michigan's plum industry.

II. **Postplant Problems (R. Perry, S. Howell, A. Iezzoni, J. Flore, A. Jones, M. Whalon, J. Johnson, G. Bird, B. Ho, H. Zapp)**

A. **Horticultural factors affecting decline of sweet cherry under Michigan conditions.** Promising new selections were tested for their mid-winter floral bud and wood deacclimation hardiness determinations. Promising new cultivars seem to be adapted to Michigan's climatic conditions.

Water stress did not effect cold hardiness of the wood during acclimation, but trees on Mazzard were more hardy than those on Mahaleb. Drought reduced starch content of the roots.

Trees on GI series 148/1 and 195/1 were 6 times more yield efficient in 1992 than trees on Mazzard rootstock.

B. **Predisposition of sweet cherry to bacterial canker.** It appears that *Pseudomonas syringae* and *Pratylenchus penetrans* and low soil pH are major factors in the sweet cherry tree decline syndrome. The sequence of events leading to tree death indicate that the impact of biotic factors increases with decreasing soil pH. The mechanisms by which low pH affects tree growth and death appears to be through increasing the availability of soil Al to toxic levels.

C. **Pheromone disruption and control of the borer complex in cherries.** Our project has accomplished several important preliminary steps toward a full scale test of pheromone disruption of the borer complex on stone fruit trees in Michigan. First, we determined the attenuation under Michigan conditions of commercial borer pheromone in two different dispensers. We found that the conventional rubber septa would not release sufficient pheromone throughout the entire flight period of borers. The 'rope' type of dispenser did release pheromone throughout the flight period and it did not degrade. Second, a large field cage for disruption studies was constructed and trialed in 1992. Third, borer rearing or maintenance of wild type colony locations were developed to accommodate the numbers necessary to artificially infest the field cage to evaluate disruption. Fourth, two ultrasound techniques were developed and tested to detect borer damage in cherry trees. We believe that a nondestructive-damage assessment system was necessary to determine if full scale pheromone disruption would work in the field. Both the disruption technique and the ultrasound detection systems will need further work before they can be commercialized in Michigan fruit production.

D. **Sustainable IPM of X-Disease in stone fruit.** X-Disease is a major factor in stone fruit decline, especially peaches. Our research has identified the major insect vectors involved by building on previous work at Michigan State University. A cDNA probe was adapted to reliably diagnose X-disease in its leafhopper vectors. This probe has greatly facilitated the epidemiological studies of X-disease. We now know that the disease's principal inoculum is in herbaceous hosts which are often found in the orchard ground cover or surrounding vegetation. Chokecherry, which was previously believed to be the most

important alternate host, does play an important role in maintenance of the disease, but is not the principal host from which the leafhoppers acquire the disease agent. Vector leafhoppers can move from surrounding vegetation into orchards, but most adults do not live long enough to acquire, incubate and transmit the disease. Instead, nymphs feeding on grass and herbaceous hosts acquire the disease. The disease progress in the insect is very temperature sensitive. Diseased leafhoppers may be killed, not affected or their development actually enhanced depending on the temperature. Thus much of the fluctuation in X-disease expression historically is probably due to the complex interactions between the infected leafhopper and ambient temperature.

The behavior of the leafhopper is much better understood as a result of our work. We now know that adult leafhoppers exhibit a crepuscular behavior where they spend most of the daylight hours in the orchard ground cover and most of the dark hours in the trees. This daily mass flight pattern can account for the level and degree of transmission of X-disease in one site. Finally, we have begun to explore noninsecticidal approaches to managing X-disease by manipulation of ground covers that are repulsive or toxic to leafhoppers. Thus, changing the orchard habitat without increasing the number of insecticide applications may be the best management approach.

E. **Development of new cold hardy peach cultivars tolerant to *Cytospora* canker.** Tolerance to *Cytospora* canker has been identified in open-pollinated peach seedlings from the Russian introduction 'Yennoh' and an exotic rootstock selection from Canada. We have initiated a backcrossing breeding program to transfer this tolerance into commercial peach selections.

III. Post Harvest Technologies for Sweet Cherries. (A. Cameron and D. Guyer)

A. **Factors affecting harvest, and post harvest quality.** Michigan State University has a strong commitment to the stone fruit industry. Significant progress has been made to reduce tree decline, but several problem areas still need attention. Emphasis in the immediate future will continue in the areas outlined above.

The focus of this project was on the fresh market sweet cherry industry. Our fundamental objective has been to improve handling, storage, and packaging techniques to extend postharvest life of sweet cherries. It is apparent the sweet cherry industry has the capability to produce a good quality cherry, but because of traditional marketing, the industry does not have a good grasp on harvesting, handling, and cooling the product for the fresh sweet cherry market. Sweet cherry maturity is another area of importance in the industry for which there appears to be consensus.

The project has demonstrated the effects of poor physical handling and has also demonstrated the positive aspects of proper handling. Similar to physical handling, the project demonstrated the problems associated with poor temperature management in any or all facets of the industry from the tree to the consumer. The maturity and color studies support the initial belief that West Coast harvest maturity factors do not match with Michigan's needs. The findings of this study show that various cultivars differ significantly in their potential for

the fresh market and that this potential can be quite dependent on the specific market being addressed.

REFERENCES

Chang, L.S., A. Iezzoni and G. Adams. 1991. Heritability of *Leucostoma persoonii* canker resistance among diverse peach genotypes. HortScience 20:60-62.

DeVries-Patterson, R.M., A.L. Jones and A.C. Cameron. 1991. Fungistatic effects of carbon dioxide in a package environment of the decay of Michigan sweet cherries by *Monilinia fructicola*. Plant Dis. 75:943-946.

Flore, J.A. 1988. Overview of the Michigan Stone Fruit Decline Project. 118th Annu. Rep. MI State Hort. Soc., Pp. 135-136.

Flore, J.A., G. Bird, A.C. Cameron. I. Gray, D.E. Guyer, B. Ho, G.S. Howell, A.F. Iezzoni, A.L. Jones, H. Melakeberhan, D.C. Ramsdell, M.E. Whalon and H.R. Zapp. Stone fruit decline progress report for 1992. Dept. Hort. Spec. Pub. 57 Pp.

Flore, J., D. Ricks, C. Harris, M. Whalon, D. Guyer, J. Hull and J. Cash. 1992. Michigan fruit industry survey. Spec. Res. Rep., MI State Univ. Agr. Expt. Sta. April. Res. Rep. 524. 32 Pp.

Guyer, D.E., N.L. Schulte and E.J. Timm. 1992. Skin and flesh color measurements of Michigan sweet cherries. ASAE paper 92-7051, The ASAE, St. Joseph, MI.

Gracia-Salazar, C., M.E. Whalon and U. Rahardja. 1991. Temperature-dependent pathogenicity of X-disease Mycoplasma-like organism to its vector, *Paraphlepsis irroratus*. Env. Entomol. 20:179-184.

Howell, G.S., Jr., J.A. Flore and T. Ditmer. 1988. Factors affecting cold hardiness of peach. 118th Ann. Rep., MI State Hort. Soc., Pp. 137-145.

Layne, D.R. and J.A. Flore. 1991. Response of young, fruiting sour cherry trees to one-time trunk injury at harvest date. J. Amer. Soc. Hort. Sci. 116:851-855.

Melakeberhan, H., A.L. Jones and G.W. Bird. 1992. Abiotic factors affecting sweet cherry trees in Michigan. J. Nematol. 24:606.

Ramsdell, D.C., G.W. Bird, V.A. Adler and J.M. Gillett. 1992. Effects of tomato ringspot virus and prunus necrotic ringspot virus alone and in combination on growth and yield of 'Montmorency' sour cherry. Acta Hort. 309:111-113.

Rahardja, U., M.E. Whalon, C. Garcia-Salazar and Y.T. Yan. 1992. Field detection of X-disease mycomplasma like organism in *Paraphlephius irroratur* using a DNA probe. Env. Entomol. 21:81-88.

Sobiczweski, P. and A.L. Jones. 1991. Effect of freezing on development of bacterial canker of sweet cherry. Phytopathology 81:1194.

PEACH TREE SHORT LIFE IN THE SOUTHEASTERN UNITED STATES: A HISTORICAL OVERVIEW

F.F. Hendrix[1]

In the 1950's it was recognized that the average life of peach orchards in much of the southeastern United States was about 8 years. The cause of tree death was proposed by various researchers to be nematodes, bacterial canker, mushroom root rot, cold injury, virus diseases, poor soil drainage, poor cultural practices, repeated plantings of peaches on the same land and borer injury (Prince, 1966; Savage and Cowart, 1942). One characteristic common to all of the short life orchards was that they were planted on old peach land.

An estimated 200,000-300,000 trees died during the spring of 1962. Prince (1966) reported that most trees which died were over 4 years old. Younger trees developed symptoms, but he reported that they tended to recover. Losses were greater in orchards where the site had previously been planted to peaches (Prince, 1966). Owen et al. (1965) reported that in the major peach production areas in Georgia, 33% of the trees were dead, and 16% of the living trees were diseased. Many trees in orchards planted on old peach land died before any fruit was harvested (Taylor, 1972).

Trees with short life frequently initiated blooms and leaves in the spring, and then collapsed. Cambial tissue was discolored from the ground up to the crotch. A characteristic sour sap odor was detectable on warm days in the spring. In many cases the entire tree collapsed, while in others only 1 or 2 of the scaffold limbs died. Roots of some trees appeared unaffected, while on others the roots died also. Sprouting frequently occurred from those with living roots. These symptoms fit those of bacterial canker and those of cold injury (Prince, 1966; Savage and Cowart, 1942).

Savage and Cowart (1942) published one of the earliest papers on the factors affecting longevity of peach trees in Georgia in 1942. They reported cold injury to be a major factor. In 1953, Savage et al. (1953) reported that Clitocybe root rot was an important factor in the complex. In 1965, Petersen and Dowler (1965) at Clemson, reported that bacterial canker was important in the complex, and that time of pruning affected the amount of bacterial canker occurring. An important point about this paper was that it suggested that more than one factor was involved. In 1966, Hendrix et al. (1966) reported that root disease fungi and nematodes were constantly associated with declining orchards. Following these two papers, it became apparent that peach tree short life (PTSL) was a decline disease with multiple causal factors. Hendrix and Powell (1969; 1970) and Taylor et al. (1970) presented evidence that nematodes, Pythium spp., hardpans, planting trees from unfumigated nurseries, and mechanical cultivation were causal factors in PTSL.

At this point, the University of Georgia College of Agriculture administration decided to form a team to investigate this disease. Plant pathologists, horticulturists, microbiologists, soil scientists and extension specialists were appointed to the team. A major advantage of this inclusion of extension specialists was that being a participant in the planning and research involved them much earlier, and they were therefore able to use research plots as demonstrations for growers. As a result, growers received the research results much faster than normal.

As this committee began its work, it became evident that many other factors were involved in PTSL. Tree nutrition and soil pH were determined by Joel Giddens and H.F. Perkins to be a major part of the disease problem. It had also been suggested that old peach roots were involved in tree death. The mode of action was postulated to be toxin production from the dead roots. Giddens and Perkins disproved this by burying large numbers of dead roots in planting holes. Daniell developed herbicide programs for peaches to eliminate mechanical cultivation that Hendrix and Powell had found to be one of the most

---

[1]Research/Extension Plant Pathology, University of Georgia Cooperative Extension Service, 4-Towers Building, Athens, GA 30602

important parts of the problem. Daniell also followed up on Petersen and Dowler's work, and demonstrated that fall and early winter pruning increased mortality to 66% instead of the 6% that occurred when trees were pruned in March. Johnstone searched for tolerant or resistant rootstocks, and developed a technique for rooting peach cuttings which will be valuable when rootstocks become available. Hendrix and Powell found that Lovell rootstock performed better than canner rootstock or Nemaguard rootstock (Daniell, 1973; Taylor, 1972).

Thus, as a result of the work of this research group, and the people working at Clemson University, a multitude of causes of PTSL were demonstrated. These included discing, lack of lime/low pH, pruning time, poor tree nutrition, hardpans, nematodes, Pythium feeder root necrosis and choice of rootstocks. While cold injury and bacterial canker were the cause of the final death of the trees, these could be prevented by reducing the tree stress caused by these factors.

In 1973, McGlohon and Spivey (1973) published a peach tree decline booklet, listing and describing the various components of the disease complex. This publication was based on the research completed by the research/extension committee. While the authors acknowledged a preference for using new land, they presented an 8-point program to improve tree survival and performance on old land. The eight points are:

1. Adjust soil pH to 6.0 or higher to a 16-inch level.
2. Apply extra nitrogen in August after harvest to keep the tree vigorous and help it withstand other problems.
3. Use Lovell rootstock.
4. Prune trees in February, March or April.
5. Subsoil before planting.
6. Use herbicides for weed control. Never disc.
7. Buy trees grown in fumigated soil.
8. Fumigate soil before planting where nematodes are a problem.

This procedure was expanded to a 10-point program in a 1978 publication authored by extension specialists in Georgia, Alabama, North Carolina, South Carolina and the USDA-SEA (Brittain and Miller, 1978). The additional 2 points were postplant fumigation where nematodes are a problem, and orchard sanitation.

This research effort paralleled a similar program in California. Major contributions since the mid-1970's include Nyczepir's work on the role of ring nematodes (*C. xenoplax* = *Mesocriconema xenoplax*) and his current work on nematode management (Nyczepir et al., 1983; Nyczepir et al., 1985). Additional work is underway on new rootstocks.

LITERATURE CITED

Brittain, J.A. and R.W. Miller Jr. (ed.). 1978. Managing Peach Tree Short Life in the Southeast. Circ. 585, Clemson Univ. Ext. Serv. 19 Pp.

Daniell, J.W. 1973. Effects of time of pruning on growth and longevity of peach trees. J. Amer. Soc. Hort. Sci. 98:383-386.

Hendrix, F.F., W.M. Powell and J.H. Owen. 1966. Relation of root necrosis caused by Pythium species to peach tree decline. Phytopathology 56A:1229-1232.

Hendrix, F.F. and W.M. Powell. 1969. Control of peach tree decline in established orchards. Down To Earth 24:14-16.

Hendrix, F.F. and W.M. Powell. 1970. Control of root pathogens in peach decline sites. Phytopathology 60:16-19.

McGlohon, N.E. and C.D. Spivey. 1973. Peach tree decline. Univ. of GA Coop. Ext. Serv. Bul. 714. 16 Pp.

Nyczepir, A.P., E.I. Zehr, S.A. Lewis and D.C. Harshman. 1983. Short life of peach trees induced by *Criconemella xenoplax*. Plant Dis. 67: 507-508.

Nyczepir, A.P., P.F. Bertrand, R.W. Miller and R.F. Motsinger. 1985. Incidence of *Criconemella* spp. and peach orchard histories in short life and non-short life sites in Georgia and South Carolina. Plant Dis. 69:874-877.

Owen J.H., W.M. Powell and F.F. Hendrix. 1965. Occurrence of peach tree decline in Georgia in 1965. Plant Dis. 49:859-860.

Petersen, D.H. and W.M. Dowler. 1965. Bacterial canker of stone fruits in the southeastern states. Plant. Dis. 49:701-702.

Prince, V.E. 1966. Winter injury to peach trees in central Georgia. Proc. Amer. Soc. Hort. Sci. 88:190-196.

Savage, E.F. and F.F. Cowart. 1942. Factors affecting peach tree longevity in Georgia. GA Agr. Expt. Sta. Bul. 259.

Savage, E.F., J.H. Weinberger, E.S. Luttrell and A.S. Rhoads. 1953. Clitocybe root rot-A disease of economic importance in Georgia peach orchards. Plant Dis. 37:269-270.

Taylor, J. 1972. Contributions to the control of Peach Decline in Georgia orchards. GA Agr. Res. Fall 1972:3-6.

Taylor, J., J.A. Biesbrock, F.F. Hendrix, W.M. Powell, J.W. Daniell and F.L. Crosby. 1970. Peach tree decline in Georgia. GA Agr. Res. Bul. 77.

CONSIDERATIONS IN PEACH ORCHARD FLOOR MANAGEMENT

W.A. Skroch[1] and C.J. Catanzaro[2]

Growers have utilized many ground cover management strategies in peach orchards over the years. Each grower must determine which orchard floor system is most appropriate for long term production on his own land. In accordance with the principles of sustainable agriculture, systems should be not only economically sound, but also socially acceptable and environmentally benign.

Trees and vegetation interact in the orchard. Competition between trees and weeds for nutrients and water can slow tree growth and delay fruit production. Common bermudagrass caused severe stunting of peach trees, which could result in a 2- to 3-year delay in fruit production (Weller et al., 1985). In a study that compared frequent mowing, hay mulch, cultivation, and herbicide treatments, frequent mowing resulted in trees that were generally lower in nitrogen, grew less, and produced less fruit. Clean culture reduces this competition, but results in soil compaction, increased runoff and erosion, and poor roadability.

The principles of sustainable agriculture tend to preclude bare ground (clean culture) as a feasible cultural practice on sloping sites. Vegetative ground covers are used to control erosion, maintain soil structure, promote water infiltration, and enable movement of orchard equipment under wet conditions (Haynes, 1980). Vegetative ground cover systems include strip cover, cover crop, and herbicide no-till.

A properly managed ground cover system can conserve soil at the same time reduce competition. However, commonly used grass ground covers such as bluegrass, tall fescue, and orchard grass compete vigorously with orchard trees. In a study in which young peach trees were planted in a tall fescue sod, tree growth increased as the size of the vegetation-free area increased (Welker and Glenn, 1985). Growth of apple trees was reduced after four years in tall broadleaf, bluegrass, orchardgrass and tall fescue plots (Shribbs and Skroch, 1986). Tree growth was higher in plots with nontraditional ground covers such as nimblewill, blackberry, legume, and red sorrel. Nimblewill has potential for replacing more competitive grasses in orchard floor systems (Shribbs and Skroch, 1986).

Another aspect of peach production affected by orchard floor management is tree microclimate. Properly managing the orchard floor could augment protection against bud tissue damage on radiation frost nights (Sharatt and Glenn, 1988). Vegetation generally limits heat absorption during the day and reradiation of heat at night. Therefore, minimizing ground cover during blossom time may reduce risk of freeze damage (Skroch and Shribbs, 1986). A vegetative cover tends to minimize diurnal fluctuations in soil temperatures (Glenn and Welker, 1987), which provides a favorable microenvironment for tree growth.

Ground covers affect the orchard indirectly through the organisms they attract. Population densities of both beneficial and detrimental organisms may be affected. Beneficial effects of ground covers, as compared to bare or cultivated soil, include increased earthworm activity (Skroch and Shribbs, 1986). Ground cover reduced infestations of nematodes, mites, and insect pests (William, 1981). Insects are known to prefer some ground covers over others. Infestations of green peach aphid were reduced in grass as compared to broadleaf weeds (Tamaki, 1975). Dandelions, sheep sorrel, and common chickweed had high frequencies of infection with tomato ringspot virus (TmRSV), which is associated with peach stem-pitting and is transmitted by nematodes (Powell et al., 1984). The ring nematode (*Criconemella xenoplax* = *Mesocriconema xenoplax*) limits growth and productivity of peach trees and increases

---

[1]Horticulturist, Department of Horticultural Science, North Carolina State University, P.O. Box 7609, Raleigh, NC 27695

[2]Graduate Research Assistant, Department of Horticultural Science, North Carolina State University, P.O. Box 7609, Raleigh, NC 27695

susceptibility to diseases and environmental stresses (Zehr et al., 1986). The nematode is an important contributing factor in the peach tree short life (PTSL) syndrome. Perennial ryegrass and tall fescue, two of the most common orchard ground covers in the Southeast, served as nematode hosts (Zehr et al., 1986). The legumes crimson clover, hairy vetch, and cowpea also served as hosts, but nimbewill did not.

Broadleaf winter annual weeds resulted in increased fruit injury (catfacing) due to feeding by hemipteran insects (Meagher and Meyer, 1990). In mowed orchards, fruit injury occurs when mowing does not precede bloom of winter annuals (Killian and Meyer, 1984). Insects are attracted to winter annuals during bloom stage, which overlaps with the initial swell period of peaches. Fruits are most susceptible to injury by catfacing insects during this period in their development (Killian and Meyer, 1984). Appropriate and timely herbicide application reduces weeds hosts, thus reducing fruit injury. An application of 2,4-D amine in mid-December eliminates many winter annuals effectively and economically. Mowing prior to tree bloom eliminates residual broadleaf weeds, and provides the added benefit of frost protection.

Tree growth and crop production may be influenced by many factors related to orchard floor management, including vegetation competition, soil properties, tree microclimate, and pest and disease pressure. Selection of an orchard floor management system that is appropriate for the intended use and site should not only maximize profits, but also provide long-term sustainability for the production system.

LITERATURE CITED

Glenn, D.M. and W.V. Welker. 1987. Soil management effects on soil temperature and heat flux in a young peach orchard. Soil Sci. 143:372-380.

Haynes, R.J. 1980. Influence of soil management practice on the orchard agro-ecosystem. Agro-Ecosystems 6:3-32.

Killian, J.C. and J.R. Meyer. 1984. Effect of orchard weed management on catfacing damage to peaches in North Carolina. J. Econ. Entomol. 77:1596-1600.

Meagher, R.L., Jr. and J.R. Meyer. 1990. Effects of ground cover management on certain abiotic and biotic interactions in peach orchard ecosystems. Crop Prot. 9:65-72.

Powell, C.A., L.B. Forer, R.F. Stouffer, J.N. Cummins, D. Gonsalves, D.A. Rosenberger, J. Hoffman and R.M. Lister. 1984. Orchard weeds as hosts of tomato ringspot and tobacco ringspot viruses. Plant Dis. 68:242-244.

Sharatt, B.S. and D.M. Glenn. 1988. Orchard floor management utilizing soil-applied coal dust for frost protection. Part I. Potential microclimate modification on radiation frost nights. Agr. For. Meterol. 43:71-82.

Shribbs, J.M. and W.A. Skroch. 1986. Influence of 12 ground cover systems on young'Smoothee Golden Delicious' apple trees: I. Growth. J. Amer. Soc. Hort. Sci. 111:525-528.

Skroch, W.A. and J.M. Shribbs. 1986. Orchard floor management: An overview. HortScience 21:390-394.

Tamaki, G. 1975. Weeds in orchards as important alternate sources of green peach aphids in late spring. Environ. Entomol. 4:958-960.

Welker, W.V. and D.M. Glenn. 1985. The relationship of sod proximity to the growth and nutrient composition of newly planted peach trees. HortScience 20:417-418.

Weller, S.C., W.A. Skroch and T.J. Monaco. 1985. Common bermudagrass (*Cynodon dactylon*) interference in newly planted peach (*Prunus persica*) trees. Weed Sci. 33:50-56.

William, R.D. 1981. Complementary interactions between weeds, weed control practices, and pests in horticultural cropping systems. HortScience 16:508-513.

Zehr, E.I., S.A. Lewis and M.J. Bonner. 1986. Some herbaceous hosts of the ring nematode (*Criconemella xenoplax*). Plant Dis. 70:1066-1069.

INFLUENCE OF BAHIAGRASS ON TREE GROWTH AND SURVIVAL[1]

D.R. Evert[2]

The productive life of peach orchards in the southeastern United States generally decreases each time an orchard site is replanted. Consequently, peach growers are continually looking for virgin sites for their orchards. Unfortunately, these virgin sites usually are remote from existing packing sheds or have imperfect water and air drainage because the good sites near the packing sheds already have been planted with peaches. The growers try to rent the virgin sites for the expected life of the orchard because they do not want to buy a site that they will plant with peaches only once. Growers with orchards on rented sites are reluctant to improve the air and water drainage, to install irrigation, or to make other improvements to increase yield, improve quality, and reduce frost injury.

An alternative to finding virgin sites is to use fumigants or nematicides before replanting a site. However, these chemicals are expensive and not always reliable. Also, fumigants and nematicides are under attack because of their toxicity and potential for damaging the environment.

I propose that peach growers in much of the Southeast could keep their best peach sites in nearly continuous peach production by growing bahiagrass sod between the tree rows. Continuous production on sites with the best air and water drainage would eliminate the need to find sites never planted with peach trees or the need to apply fumigants or nematicides. With continuous production on the best sites, growers could buy the sites and make all needed improvements like irrigation and tiling of wet spots.

---

[1]Supported in part by a grant from the Southern Region Pesticide Impact Assessment Program.

[2]Research Horticulturist, University of Georgia, Coastal Plain Experiment Station, P.O. Box 748, Tifton, GA 31793

Let me list the steps growers would follow to keep a site in continuous peach production and then present some data to support my proposal.

1. Two years before planting trees, establish a bahiagrass sod where trees will be planted. In an existing orchard, plant bahiagrass between the tree rows two or more years before removing the existing orchard. The two years allows a thick, weed-free sod to develop.

2. Lime and fertilize the sod and the trees, if present, and mow the sod to insure it is vigorous and free of weeds.

3. Apply no preemergent herbicides to the tree rows the summer before the orchard will be removed, so that the bahiagrass can begin to spread under the trees.

4. Apply contact herbicides under the trees, if necessary, to reduce competition between the grass and the trees during the final year of production.

5. Remove the existing trees immediately after the last harvest so that the bahiagrass can grow and the peach roots can die before new trees are planted.

6. Prepare new tree rows by killing strips in the sod with herbicides. Spray the herbicides in the late fall while the grass is still growing or in the spring after the grass has resumed growth. All grass must be killed in the new tree-rows to avoid stunting of the young trees.

7. Subsoil and cross-subsoil the planting sites and then plant the trees. No additional land preparation is necessary.

8. Apply herbicides to the new tree-rows to keep them free of grass and weeds.

9. Mow and fertilize to encourage the bahiagrass to form a thick sod where there were tree rows in the previous orchard.

10. Repeat these steps whenever an orchard needs replanting.

Support for this proposal comes from studies of nematode populations and from tree survival and growth in orchards with bahiagrass-sod between the tree rows. Data taken in these orchards show that peach roots prevent bahiagrass from eliminating all *Meloidogyne* spp. and *Criconemella xenoplax* (Raski) Luc and Raski (=*Mesocriconema xenoplax*). However, bahiagrass can be used to create sites in the orchards that are free of peach roots and damaging nematodes. A replacement orchard can be successfully established by planting trees at these sites.

NEMATODE CONTROL

Bertrand and Nyczepir (1989) list the nematodes damaging to peach trees in Georgia as root-knot (*Meloidogyne* spp.), ring (*C. xenoplax*), and lesion (*Pratylenchus vulnus* Allen and Jensen). Root-knot and ring nematodes cause major damage to peach trees in the Southeastern states, and *P. vulnus* causes less damage. *Pratylenchus vulnus* was not a problem in orchards with bahiagrass-sod. The nematode populations in these orchards in 1986-1988 were determined for more than 300 soil samples collected in the surface 25 cm of soil. Most of the samples were free of *P. vulnus*, and only one sample had a *P. vulnus* population as high as 20 per 150 cm^3 of soil.

Root-knot: The *Meloidogyne* spp. are considered as a group because all of them produce knots on susceptible peach rootstocks. More research has been done on Pensacola bahiagrass than on any other bahiagrass cultivar. In the field, solid stands of each bahiagrass cultivar suppressed *Meloidogyne* spp. (Dickson and Hewlett, 1989; McBeth, 1945; McGlohon et al., 1961). In pot studies some bahiagrass cultivars were immune to all species of *Meloidogyne* tested (McGlohon et al., 1961). None of the reports showed that bahiagrass eliminated *Meloidogyne* spp. under field conditions if roots of susceptible plants were present.

Experiment 1. The *Meloidogyne* populations in the tree rows of the previous orchard averaged 19 times those in the sod under the drip line of the previous trees (Table 1). The populations were measured immediately before the new trees were planted. The roots of peach trees in the previous orchard had visible knots in the sod and in the row. This experiment also involved preplant fumigation with methyl bromide and different rootstocks. Neither preplant fumigation nor rootstock had an effect on the populations of *Meloidogyne* spp. measured in Jan. 1990 before planting nor in Apr. 1990 after tree planting (data not shown).

The four grasses used in this study gave equivalent control of *Meloidogyne* spp. under field conditions (Table 1). In pot studies, 'Coastal' Bermudagrass was immune to the five species of *Meloidogyne* while 'Pensacola' bahiagrass was classified as resistant or immune depending upon the nematode spp. (McGlohon et al., 1961). 'Paraguayan 22' bahiagrass like 'Pensacola' bahiagrass suppressed populations of *Meloidogyne* spp. (Evert et al., 1992). Unfortunately, peach trees make poor growth if planted in either live bahiagrass or bermudagrass (Evert et al., 1992; Weller et al., 1985).

Knots on peach roots in the sod show that trees in a replacement orchard must be planted as far as possible from the old trees.

Ring: Although *Meloidogyne* spp. stunt the growth of peach trees and can kill newly planted trees, most researchers feel that *Criconemella xenoplax* causes most peach tree decline. At least two species of *Criconemella* are found in peach orchards in the Southeast. Besides *C. xenoplax*, peach orchards may have *C. ornata*. *C. ornata* is a grass feeder that does not multiply on peach roots (Ratanaworabhan and Smart, 1970). Because both *C. ornata* and

C. xenoplax can occur in peach orchards, ring nematodes must be identified to species.

Experiment 1. Average populations of *C. ornata* were higher than *C. xenoplax* on all dates for this experiment (data not shown). *Criconemella xenoplax* populations in Jan. 1990 averaged less than one per 150 cm^3 for all treatments (Table 2), but the populations of *C. xenoplax* were less in the sod under the drip line than in the tree row. No *C. xenoplax* nematodes were detected in Apr. 1990 at sites preplant fumigated with methyl bromide while the average population was 0.4 per 150 cm^3 at nonfumigated sites ($P = 0.05$).

The average population of *C. xenoplax* was lowest under 'Coastal' bermudagrass and highest under 'Pensacola' bahiagrass (Table 2). However, 'Coastal' bermudagrass has several faults that limit its value in peach orchards. Bermudagrasses spread aggressively (Horowitz, 1972). Bermudagrasses also have a higher nitrogen requirement than bahiagrasses. Also, 'Coastal' bermudagrass must be established with sprigs while the bahiagrasses can be seeded.

Experiment 2. This study confirmed that 'Paraguayan 22' bahiagrass suppressed *C. xenoplax* and *C. ornata* in peach orchards (Table 3). The orchard was planted on a slope with the tree rows running across the slope. Tree rows on either side of the sod middles were sampled to see if soil erosion or rain might move nematodes down the slope. The data for both species show that bahiagrass-sod restricts the movement of nematodes. Neither root-knot nor root-lesion nematodes were present at this site. Typical symptoms of peach tree short life (PTSL) were observed on trees at this site.

Experiment 3. A detailed study of *C. ornata* and *C. xenoplax* populations in an established orchard is shown in Table 4. The data on 18 Mar. 1987 confirm that 'Paraguayan 22' bahiagrass suppressed *C. xenoplax*. Populations of *C. ornata* on the same date were highest midway between the trees in the previous orchard. The principal weed at these locations was common bermudagrass. At the end of the first growing season on 5 Nov. 1987, the populations of *C. xenoplax* and *C. ornata* were independent of location.

TREE GROWTH AND SURVIVAL

Nematode populations are important in discussion of peach orchard establishment, but tree survival and growth are more important. Live bahiagrass growing under newly planted trees caused severe stunting although tree survival in the grass was good if no fenamiphos was applied after planting (Evert et al., 1992).

Experiment 1. Populations of *Meloidogyne* spp. (Table 1) and *C. xenoplax* (Table 2) were lower at sites in the sod than at sites in the tree rows of the previous orchard, but there was no corresponding increase in tree survival or growth (data not shown). However, there were no planting sites in killed bahiagrass midway between the previous tree rows. The experiment did include preplant fumigation with methyl bromide and the use of Lovell and Nemaguard rootstocks.

The preplant fumigation with methyl bromide provided some valuable information. Six trees, all at nonfumigated sites, died the first winter. Tree loss at fumigated and nonfumigated sites was equivalent ($P>0.10$, Fisher's exact test), but the trend suggests future problems. The response to each treatment was independent of the other treatments for tree survival and growth. Trees were significantly larger ($P = 0.05$) at sites fumigated with methyl bromide than at nonfumigated sites. At the end of the first summer, trees at fumigated sites had an average cross-sectional area 1.5 times the area of trees at nonfumigated sites. These results show that without fumigation trees planted in the rows of a previous orchard or in the sod but under the drip line of the previous trees probably will have unacceptable tree survival and growth.

Experiment 3. Of the 49 trees planted in killed bahiagrass and midway between the tree rows in the previous orchard only one died during the two years of this experiment (Table 5). The loss of one tree was less ($P = 0.05$) than nine and ten trees that died at the two planting sites in the tree rows of the previous orchard. The tree that died in the killed sod died the first spring. Also, trees in the killed bahiagrass grew better the first summer than trees at either site in the previous tree rows. At the end of the second growing season, trees in the killed-sod had heavier tops. This provided more evidence of the benefit of planting in killed sod midway between the previous tree rows.

OTHER BENEFITS

Bahiagrasses have several other positive effects. Blue (1979) studied a white clover-'Pensacola' bahiagrass field over a 25 year period. He reported that "Soil organic matter averaged slightly over 2% in 1953 and approximately 4.5% in 1977." Similar increases occurred in the soil organic matter for both the limed and unlimed plots. The cation exchange capacity of the soil and exchangeable Ca also increased in the limed and unlimed plots. Forage was harvested from all plots five times each year. The increase in organic matter should be greater in the soils of peach orchards than in the plots studied by Blue (1979) because no forage would be removed from the orchards. Blue and Graetz (1977) reported that the large stolon-root system of bahiagrass absorbed and stored large quantities of nitrogen. This ability to store nitrogen nearly eliminates the loss of nitrogen by leaching and denitrification. Nitrogen loss by leaching is further reduced by a root system that extended more than five feet into the soil. The sod was irrigated whenever 85% of the available soil moisture had been removed in the surface two feet (Doss et al., 1967). In the orchard where the mowed grass is not removed, the nitrogen would be recycled each time the grass is mowed.

In conclusion, peach growers in the southeastern states probably can keep their best orchard sites in nearly continuous peach production if they plant new trees in the middle of the killed bahiagrass-sod that grew between the rows of the previous orchard.

LITERATURE CITED

Bertrand, P.F. and A.P. Nyczepir. 1989. Nematodes, Pp. 146-151. In: S.C. Myers (ed.) Peach Production Handbook. GA Ext. Serv. Hdbk. 1, Coop. Ext. Serv. The Univ. of GA, Athens, GA. 221 Pp.

Blue, W.G. 1979. Forage production and N nitrogen contents, and soil changes during 25 years of continuous white clover-Pensacola bahiagrass *Paspalum notatum* growth on a Florida Spodosol Limed treatments. Agron. J. 71(5):795-798.

Blue, W.G. and D.A. Graetz. 1977. The effect of split nitrogen applications on nitrogen uptake by Pensacola bahiagrass from an Aeric Haplaquod. Soil Sci. Soc. Amer. J. 41:927-930.

Dickson, D.W. and T.E. Hewlett. 1989. Effects of bahiagrass and nematicides on *Meloidogyne arenaria* on peanut. J. Nematol. 21(4S):671-676.

Doss, B.D., D.A. Ashley and O.L. Bennett. 1967. Effect of soil moisture regime on root distribution of warm season forage species. Agron. J. 52:569-572.

Evert, D.R. and P.F. Bertrand. 1993. Survival and growth of peach trees planted in killed bahiagrass at an old orchard site. HortScience 28(1):26-28.

Evert, D.R., P.F. Bertrand and B.G. Mullinix, Jr. 1992. Nematode populations and peach tree survival, growth, and nutrition at an old orchard site. J. Amer. Soc. Hort. Sci. 117(1):6-13.

Horowitz, M. 1972. Spatial growth of *Cynodon dactylon* (L.) Pers. Weed Res. 12:373-383.

McBeth, C.W. 1945. Tests on the susceptibility and resistance of several southern grasses to the root-knot nematode, *Heterodera marioni*. Proc. Helminthol. Soc. Wash. 12:41-44.

McGlohon, N.E., J.N. Sasser and R.T. Sherwood. 1961. Investigations of plant-parasitic nematodes associated with forage crops in North Carolina. NC Agr. Expt. Sta. Tech. Bul. 148, 39 Pp.

Ratanaworabhan, S. and G.C. Smart, Jr. 1970. The ring nematode, *Criconemoides ornatus*, on peach and centipede grass. J. Nematol. 2:204-208.

Weller, S.C., W.A. Shrock and T.J. Monaco. 1985. Common bermudagrass (*Cynodon dactylon*) interference in newly planted peach (*Prunus persica* cultivar Norman) trees. Weed Sci. 33(1):50-56.

Table 1. *Meloidogyne* spp. (Root-knot) populations per 150 cm^3 of the surface 25 cm of soil in Jan. 1990 by grass and location.

Treatment	*Meloidogyne* spp.
Grass (G)	
Bahiagrass, Pensacola	5 a[Z]
Bermudagrass, 44	4 a
Bermudagrass, Coastal	4 a
Bahiagrass, Paraguayan 22	4 a
Location (L)	
Row	19 a
Sod under drip line	1 b

Trees and grass middles were planted in 1980.

[Z]Letters indicate significance (P = 0.05) according to Tukey's test. The interactions between Grass and Location were not significant at the 5% level. Means of 36 observations for Grass, 72 observations for Location. Nematode counts (N) were transformed before analysis using log(N+3/8) to stabilize the variance, and means were back transformed for presentation.

Table 2. *Criconemella* spp. populations per 150 cm^3 of the 25 cm of surface soil in Jan. 1990 by grass and location.

Treatment	*C. xenoplax*	*C. ornata*
Grass (G)		
Bahiagrass, Pensacola	0.4 a[Z]	6.5 a
Bermudagrass, 44	0.2 ab	4.0 ab
Bermudagrass, Coastal	0.0 b	2.4 ab
Bahiagrass, Paraguayan 22	0.2 ab	0.8 b
Location (L)		
Row	0.3 a	2.7 a
Sod under drip line	0.1 b	2.8 a

[Z]Letters indicate significance (P = 0.05) according to Tukey's test. Means of 36 observations for Grass, 72 observations for Location and Rootstock, and 48 observations for Preparation. Nematode counts (N) were transformed before analysis using log(N+3/8) to stabilize the variance, and means were back transformed for presentation.

Table 3. Nematode populations per 150 cm^3 of soil in killed 'Paraguayan 22' bahiagrass and adjacent tree rows.

Nematode	*C. ornata*	*C. xenoplax*
Tree row above	8 ab	30 a[z]
Sod middle	3 b	1 b
Tree row below	23 a	9 a

[z]Letters for each species indicate significance (P = 0.05) according to Tukey's test. Means are from 18 soil samples collected Feb. 1988 from the surface 25 cm, and nematode populations were log transformed for analysis and back transformed for presentation. The bahiagrass had been planted in 1980 and killed with herbicide in Nov. 1987.

Table 4. *Criconemella* spp. populations per 150 cm^3 of soil sampled under peach trees planted at sites relative to trees in the previous peach orchard. (Evert and Bertrand, 1993).

New tree site	*C. ornata*	*C. xenoplax*
18 Mar. 1987		
Sod, middle[z]	2.1 b[y]	0.1 b
Row, between trees	7.0 a	2.7 a
Row, at trees	2.8 b	3.2 a
5 Nov. 1987		
Sod, middle	3.7 a	0.3 a
Row, between trees	4.3 a	0.2 a
Row, at trees	3.4 a	0.1 a

[z]Sod = Paraguayan 22.
[y]Letters within a date for each nematode species indicate significance (P=0.05) according to Tukey's test. Each mean is composed of 48 observations, and nematode populations were log transformed for analysis and back transformed for presentation. The sod was killed with a herbicide in Nov. 1986 and new trees planted Feb. 1987.

Table 5. Tree survival and increase in trunk cross sectional area (ITCSA) of live trees at end of first summer, November 1987, and fresh weight of tops of live trees on 7 October 1988 in response to preplant harrowing and planting site relative to trees in the previous orchard (Evert and Bertrand, 1993).

Treatment	Survival (%)	ITCSA (cm^3)	No. live	Top Fresh weight (kg)
Preplant harrowed				
No	89 a[z]	6.5 a	64	11.2 a
Yes	83 a	29.5 a	60	11.8 a
Tree site				
Sod, middle	98 a	10.6 a	47	14.0 a
Row, between trees	79 b	9.0 b	38	11.0 b
Row, at trees	81 b	7.1 c	39	9.4 b

[z]Letters within a main effect indicate significance (P=0.05) according to Tukey's test.

METHODS FOR ESTABLISHING NIMBLEWILL FROM SEED AS A GROUND COVER FOR PEACH ORCHARDS[1,2]

W.C. Olien[3], J.D. Ridley[3],
T. Whitwell[3], W.A. (Tony) Watson[4]
and W.C. Newall[3]

INTRODUCTION

Premature death of peach trees caused by peach tree short life (PTSL) is a major problem in the Southeastern states and is associated with sandy soils infested with ring nematode [*Criconemella xenoplax* (Raski) Luc & Raski (=*Mesocriconema xenoplax*)] (Ritchie and Clayton, 1981; Yadava and Doud, 1980). Expense and loss of registered materials for control of ring nematode through preplant soil fumigation and postplant application of nematicides have made alternative control measures imperative. Previous studies have found that nimblewill (*Muhlenbergia schreberi* J.F. Gmel.), a short statured, warm season, perennializing, C_4 grass (Smith and Martin, 1987), is effective in reducing ring nematode populations alone, and in the presence of peach trees (Meyer et al., 1992; Zehr et al., 1986).

Nimblewill also has the advantage of not reducing the growth of peach trees (Meyer et al., 1992). It has been found that many of the orchard ground covers in common use are strongly competitive with the growth of peach trees, even if present only in the drive row area (Glenn and Welker, 1988, 1991; Skrock and Shribbs, 1986). Thus nimblewill would have advantages as a ground cover even in orchards which do not suffer from ring nematode infestation.

The previous work discussed above has established the promising potential for nimblewill as a superior ground cover for peach orchards. However, if this potential is to be realized in commercial peach production, several aspects must be evaluated. First, a method must be found to economically establish the nimblewill ground cover from seed in young and established peach orchards. Secondly, the long term ease and practicality of maintaining this relatively noncompetitive grass must be evaluated, especially in the warmer peach production areas.

This paper reports work in progress on the first of these goals, to develop practical means of establishing a nimblewill ground cover from seed under actual orchard conditions. Subsequently, these orchard plots will be monitored to evaluate the ease of maintaining a nimblewill ground cover in the orchard.

METHODS AND RESULTS

Nimblewill seed collection. Nimblewill seed was collected in October 1991 from an orchard located at the NC Mountain Horticultural Crops Research Station in Fletcher, NC in 1990 and 1992. Overall germination of the 1990 seed lot was over 95%. Germination rate was zero immediately after collection. Germination rate of the 1990 seed lot increased to 95% after four months of storage, while the 1992 seed lot achieved a germination rate of ca. 80% under laboratory conditions after 4 months of cold storage (10 C).

Two methods were tried in collecting seed in 1991. In the first collection, nimblewill straw with seed heads was cut, collected in plastic bags, and transported to Clemson to be dried on a greenhouse bench. The straw was turned at least once a day to prevent decay. Once dry, seed was separated from the straw by screening and beating in paper bags. This was slow and labor

---

[1]This project is supported by funds from the Peach Tree Short Life special USDA grant and by a grant from the South Carolina IPM Fund for 1991-1993.

[2]The authors express their appreciation to Dr. W. Skroch (N.C. State University), for allowing us access to a source of nimblewill seed at the Mountain Horticultural Crops Research Station, Fletcher, NC

[3]Department of Horticulture, Clemson University, Clemson, SC 23634-0375

[4]County Extension Director, Clemson University, Box 509, Edgefield, SC 29824

intensive. The seed was then packaged in labeled paper bags and stored under cool conditions (10 C) at the South Carolina Foundation Seed facility on the Clemson campus.

In the second collection, made about one week after the first collection, a parking lot vacuum was run over the nimblewill plants in the field at the Fletcher collection site. This proved to be an efficient means to collect quantities of clean seed. Additional cleaning was not necessary. As before, the seed was transported to Clemson and dried on the greenhouse bench prior to storage at the South Carolina Foundation seed facility.

Factors affecting germination of nimblewill seed. Nimblewill seed germination tests were conducted by placing seeds on moist filter paper in Petri dishes in the laboratory after 0, 3, 6, and 16 weeks of cold storage. Germination was conducted in a growth room at 23 C, with the Petri dishes held under light or dark conditions. Some germination occurred with no chill period, but germination was greatly enhanced by a minimum of six weeks of moist chilling. After six weeks of chilling, limited germination occurred in the dark, but germination was always much greater with light exposure.

Determination of optimum seeding rate. Seed used to determine optimum seeding rate was collected in October 1990 from the same field used for seed collected in 1991. Germination of this seed lot was near 90%, better than the 1991 seed. Fumigation plots were established in an open field (full sun exposure) in April 1991 at Musser Fruit Research Center, Seneca, SC to determine optimum seeding rates for nimblewill. Individual 1 x 1 m plots were seeded at rates of 5.6, 16.8, and 50.4 kg/ha (5, 15, and 45 lb/acre), with six replications in a randomized complete block design. Germination in the field was very good and it appeared that the 16.8 kg/ha rate would be sufficient to effectively establish nimblewill in orchards. The plots were sprinkler irrigated frequently during the season, but no follow-up mowing or herbicides were used in these plots. By midsummer the plots were taken over by crabgrass. Nimblewill will not out compete competitive grasses on its own, at least in full sun conditions under South Carolina conditions.

1992 Establishment of nimblewill in orchard plots. Plots were established in orchard sites at Ridge Springs and at the Musser Fruit Research Center to compare tree row areas maintained weed-free with herbicides (conventional) with row strips seeded with nimblewill. Control plots were maintained with normal herbicide treatment. Twice as many nimblewill lots as control plots were established. This was done so that this fall and next year the nimblewill plots can be divided between plus and minus herbicide treatments. Low rates of selected herbicides have been observed to selectively encourage nimblewill growth in unreplicated trials in North Carolina (W.A. Skroch and E. Whitmen, pers. comm.). Five replications of each plot type (4 trees/plot) were established in Ridge Springs, and four replications (3 trees/plot) at Musser.

Nimblewill plots were seeded using a calibrated drop-seeder at a rate of 22.4 kg/ha (20 lb/acre). Activated charcoal was applied at a rate of 3.30 kg/100 m^2 (6.7 lb/1000 sq. ft.) on top of the seed in the Musser site to deactivate Karmex (diuron) herbicide residues. This was not necessary at the Ridge Springs site. Clean straw was spread over the seed after planting. A micro-sprinkler system was installed in the plots at Ridge Springs, but irrigation was not available at Musser.

Soil samples were collected from the Ridge Springs site from each of the 15 plots at the time of seeding and were transported to Clemson to obtain ring nematode counts. Plots ranged from 36 to 480 ring nematodes/100 cm^3 of soil, and averaged 164 nematodes/100 cm^3 over all 15 plots. The Musser site is not infested with ring nematodes, but offers a different soil type and climate to evaluate nimblewill as a non-competitive (with peach) ground cover for the Piedmont Region.

Germination in the field was generally poor this year from the 1991 seed lot. However, some

nimblewill did establish in all seeded plots. From past observations in South Carolina, it seems likely that seed will continue to germinate through next season. We intend to reseed these plots this fall and/or next spring to increase the nimblewill stand.

Response of nimblewill to selective herbicides. An initial greenhouse test was conducted in 1992 to determine which herbicides might be used to selectively favor nimblewill growth over other weeds, without damaging the nimblewill. Nimblewill sensitivity to two rates of each of seven herbicides was evaluated by foliar application at two nimblewill growth stages, plus a nontreated control of each nimblewill growth stage (Table 1).

Nimblewill was seeded in 5-cm pots on two dates, one month apart. All pots received herbicide treatments when the older grass had 6 to 10 tillers (old plants), and young grass had 4 leaves with no tillers (young plants). Herbicide treatments were applied by foliar sprays at rates equivalent to 0.5 x and 1 x the recommended rates. Visual rating of injury was made 7, 16, and 28 days after herbicide application, ranging from a rating of 0 (no injury) to 100 (dead). Plants fresh weight was measured at termination of the study, 28 days after herbicide application. Injury rating at 28 days are reported here (Table 1).

Simazine, pendimethalin, and bentazon were the least injurious to nimblewill. The high rate of simazine caused reduction in fresh weight of the early growth stage. All rates of herbicides tested reduced fresh weight of the later growth stage compared to control. Fenoxaprop and sethoxydim injured the older nimblewill moderately and the younger nimblewill severely. Diuron and terbacil killed nimblewill at both growth stages and application rates. Simazine and pendimethalin are preemergence herbicides that could be applied after nimblewill emergence to prevent other weed from becoming established. Bentazon is a postemergence herbicide effective in suppressing yellow nutsedge and controlling several broadleaf weeds. Nimblewill is tolerant to this herbicide. Other experiments should be conducted to determine tolerance of nimblewill to other herbicides and to determine herbicide residue effects on nimblewill emergence. Lower rates of sethoxydim and fenoxaprop will also be evaluated for nimblewill tolerance at different growth stages.

CONCLUSIONS

Previous reports have demonstrated that nimblewill reduces ring nematode populations in soil, and therefore might provide a replacement for nematicides in the management of PTSL. Nimblewill also does not reduce the growth rate of young peach trees, making this grass superior to many commonly used ground covers in peach orchards. However, this potential can only be realized in commercial peach production if the grass can be established in orchards in an economical and practical means for large areas. This requires establishment of the nimblewill ground cover from seed under orchard conditions. We have found that the noncompetitive growth of nimblewill makes it a difficult grass to establish. Also, seed germination from the same source appears to be variable from year to year. However, we have been able to establish low and variable nimblewill stands in the field in all tests so far. Out initial work with herbicides also suggests that it may be beneficial in the early establishment of nimblewill to use selective herbicides at low rates.

LITERATURE CITED

Glenn, D.M. and W.V. Welker. 1988. Growth responses of young peach trees and changes in soil characteristics with sod and conventional planting systems. J. Amer. Soc. Hort. Sci. 113(5):652-656.

Glenn, D.M. and W.V. Welker. 1991. Soil management affects shoot and root growth, nutrient availability, and water uptake of young peach trees. J. Amer. Soc. Hort. Sci. 116(2):238-241.

Meyer, J.R., E.I. Zehr, R.L. Meagher, Jr. and S.K. Salvo. 1992. Survival and growth of peach trees and pest populations in orchard plots managed with experimental ground covers. Agr., Ecosystems and Env. 41:353-363.

Ritchie, D.F. and C.N. Clayton. 1981. Peach tree short life: A complex of interacting factors. Plant Dis. 65:462-469.

Skroch, W.A. and J.M. Shribbs. 1986. Orchard floor management: An overview. HortScience 21(3):390-394.

Smith, M. and C.E. Martin. 1987. Growth and morphological responses to irradiance in three forest understory species of C_4 grass genus *Muhlenbergia*. Bot. Gaz. 148(2):141-148.

Yadava, U.L. and S.L. Doud. 1980. The short life and replant problems of deciduous fruit trees. Hort. Rev. 2:1-116.

Zehr, E.I., S.A. Lewis and M.J. Bonner. 1986. Some herbaceous hosts of the ring nematode (*Criconemella xenoplax*). Plant Dis. 70:1066-1069.

Table 1. Nimblewill herbicide tolerance - 1992.

Herbicide treatments	Common name	Normal use	Rate (lb a.i./acre)[z]	Nimblewill Response (% Injury) Young	Old
Princep EC	simazine	Preemergence	1.5	22 *	8
			3.0	48 *	12 *
Pendulam WP	pendimethalin	Preemergence	1.5	23 *	8
			3.0	28 *	5
Basagran EC	bentazon	Postemergence	1.0	22 *	10 *
			2.0	13	7
Poast EC	sethoxydim	Postemergence	0.15	73 *	33 *
			0.30	65 *	33 *
Acclaim EC	fenoxaprop	Postemergence	0.15	98 *	23 *
			0.30	65 *	28 *
Karmex WP	diuron	Preemergence	1.5	100 *	100 *
			3.0	100 *	100 *
Sinbar WP	terbacil	Preemergence	0.75	100 *	100 *
			1.5	100 *	100 *
Control				0	0

[z]Application rates equivalent to 0.5 X and 1 X.
*Significantly different from control, within columns, at the 5% probability level.

ORCHARD FLOOR MANAGEMENT FOR STONE FRUIT

D.M. Glenn[1]

Research at the Appalachian Fruit Research Station over the past 9 years has developed an orchard floor management system, termed killed-sod, that increases soil organic matter and water infiltration rate while reducing rainfall runoff and soil density. The killed-sod system relies on the establishment of a permanent sod 1 to 2 years before the trees are planted. The tree row strip is killed with herbicides at the time of tree planting and the trees planted directly into the "killed-sod" mulch. The killed-sod mulch provides complete soil cover for two years in the Mid-Atlantic region. A non-competitive soil cover is necessary in a young orchard to ensure vigorous tree growth and to prevent rainfall impact from degrading soil surface structure and enhancing the runoff and erosion potential. The killed-sod mulch is entirely degraded by the third growing season; however, full tree canopy development and improved soil structure continues to reduce the erosion and runoff potential relative to conventional practices that maintain a bare soil surface. The killed-sod system is viewed as a feasible alternative to conventional orchard establishment practices. The increased vigor of trees grown in a killed-sod system is advantageous for a young orchard because the trees fill their allotted space in the orchard more quickly and have larger, early fruit yields compared to the conventional orchard establishment practices. However, excessive tree vigor in mature trees reduces light penetration into the canopy and increases pruning cost, and the orchard floor management system should be modified to prevent excessive tree growth.

Re-establishing a perennial ground cover beneath fruit trees, leaving only a 50 to 100-cm-wide weed-free strip beneath trees has the potential to reduce vegetative growth in the deep soils of the mid-Atlantic region. In a six-year study of 'Summerglo' peach on 'Lovell' rootstock, a 50 or 100-cm-wide strip bordered by K-31 fescue sod reduced total fruit yield, but the yield of peaches $\geq$ 64 mm was not significantly reduced compared to the conventional 3-m-wide weed-free strip beneath the trees. The 50 and 100-cm-wide strip greatly reduced vertical shoot growth and increased canopy light penetration compared to the 3-m-wide strip. Re-establishing K-31 tall fescue sod in a mature orchard without irrigation does increase the risk of economic yield loss with only modest potential gains in reduced pruning costs. However, the soil conservation benefits are great. Other less competitive cover crops may provide the soil conservation benefits with less risk of yield loss and can be a part of the integrated pest management system if the cover crops attract beneficial insects into the orchard. A multidisciplinary research team at AFRS is studying how more diverse plant communities in the orchard can contribute to reduced need for pesticide application.

In summary, orchard floor management is more than a static system of soil management practices addressing weed control and plant nutrition problems. Orchard floor management impacts every aspect of deciduous tree fruit production. Orchard floor management is a dynamic process that focuses on the ever changing needs of the fruit tree. Practices that are useful for a young orchard may need changing when the orchard is mature. Orchard floor management also has undeveloped potential in the management of disease and insect pests.

---

[1]Soil Scientist, USDA-ARS, Appalachian Fruit Research Station, 45 Wiltshire Road, Kearneysville, WV 25430

IMPROVED PEACH TREE PRODUCTIVITY AND SURVIVAL ON A NEW ROOTSTOCK SELECTION

G.L. Reighard[1], W.C. Newall[1], E.I. Zehr[2], W.R. Okie[3] and T.G. Beckman[3]

INTRODUCTION

Peach tree short life (PTSL), a syndrome that involves ring nematode (*Criconemella xenoplax* = *Mesocriconema xenoplax*) and either bacterial canker (*Pseudomonas syringae* pv. *syringae*) or cold injury, still occurs in peach orchards throughout the southeastern United States (Ritchie and Clayton, 1981). Rootstocks significantly influence tree susceptibility to PTSL (Zehr et al., 1976; Reighard et al., 1990a). Greenhouse screening of peach germplasm for ring nematode resistance has not found a *Prunus persica* genotype that is a poor host for ring nematode (Westcott and Zehr, 1990). Field screening studies, however, have selected some peach genotypes that are more tolerant to PTSL than Lovell, the recommended commercial rootstock (Beckman, 1990; Reighard et al., 1990b). The objective of this study was to evaluate these tolerant selections as rootstocks on a severe PTSL site to determine if the initial observations of increased tree longevity of these genotypes could be imparted to budded commercial peach cultivars.

MATERIALS AND METHODS

Virus-free 'Redhaven' and 'Springcrest' peach cultivars were budded in June 1988 to seedlings from 10 open-pollinated peach lines selected for their superior survival in a 7-year-old screening test on a severe PTSL site (Reighard et al., 1990b). These lines were BY520-8, BY520-9, Bailey, Blue Goose plum, Boone County, BY7446 plum, Edible Sloe plum, Ferris Strain, Tennessee Natural No. 55, and Transvaal Yellow. In addition, the two scion cultivars were also budded to virus-free Lovell and Nemaguard seedling rootstocks. Springcrest was not budded to Bailey nor BY520-8; thus, a total of 22 scion/rootstock combinations (i.e., =stion) were included in the test. There were 20 trees per stion except for the Blue Goose and Edible Sloe plums which had 7-10 trees per stion due to tree loss from incompatibility. Also, there were only 13, 13, and 15 trees of 'Springcrest' on BY520-9, Boone County, and Lovell, respectively.

The trees were planted 17 Jan. 1989 in a completely randomized design on a Lakeland sand (thermic, coated Typic Quartzipsamments) at the Sandhill Research and Education Center near Pontiac, South Carolina. The orchard site has a long history of peach trees dying from PTSL. The trees were planted in the same rows where a peach orchard had been in 1988. The soil was not fumigated nor limed before planting. No supplemental irrigation was provided after planting. Bloom dates were taken during March 1992. Tree death and bacterial canker infection were recorded 2 May 1991 and 22 Apr. 1992. Bacterial canker infection was rated on a 0-5 scale according to the method (see Table 3) developed by Zehr and reported by Reighard (1990). Mortality and bacterial canker ratings from the two years were combined for analysis. Root sucker sprouts were counted on 13 May 1992. Trunk cross-sectional area was measured at 5 cm above the soil surface on 6 Oct. 1992. All data were analyzed using the SAS GLM procedure. Differences among treatment means were separated by Waller-Duncan K-ratio T test ($P = 0.05$).

RESULTS AND DISCUSSION

Highly significant differences in bloom date, trunk cross-sectional area, crown or root suckers, bacterial canker infection, and PTSL death were found among the rootstock/scion (=stion) combinations after four years in the field. No yield data were collected in 1992 because of a complete crop failure from an April freeze. Bloom dates of 'Redhaven' and 'Springcrest' when compared to trees on Lovell

[1]Clemson University, Department of Horticulture, Box 340375, Clemson, SC 29634

[2]Clemson University, Department of Plant Pathology and Physiology, 218 Long Hall, Clemson, SC 29634

[3]Research Horticulturists, USDA-ARS, Southeastern Fruit and Tree Nut Research Laboratory, P.O. Box 87, Byron, GA 31008

were advanced by 2-6 and 1-2 days, respectively, on all rootstocks except Nemaguard and Tennessee Natural (Table 1). Cultivars on Blue Goose and BY7446 plums bloomed the earliest. Rootstocks influenced bloom date of the high chilling 'Redhaven' cultivar more than they did the medium chilling 'Springcrest'.

'Redhaven' tree growth was significantly greater on the BY520-8 and BY520-9 rootstocks than on Lovell rootstock (Table 2). No other rootstock with 'Redhaven' had significantly larger trees than Lovell. 'Springcrest' growth was similarly affected; however, Tennessee Natural and Nemaguard produced trees as vigorous as BY520-9. Although 'Redhaven' and 'Springcrest' tree growth differed among rootstocks, their tree growth was similar when averaged across all rootstocks. Trunk cross-sectional area of both scion cultivars during the first 3 years was least on the plum rootstocks BY7446, Blue Goose, and Edible Sloe (data not shown) , but by year 4 growth on these plum rootstocks had equaled or exceeded that of the root-knot nematode susceptible peach rootstocks. Since root-knot nematodes were present (data not shown), this suggested that tree growth on nonfumigated soils is significantly influenced by root-knot nematode infection.

Nemaguard, BY7446, and Edible Sloe had significantly more suckers per tree than Lovell and the other rootstock lines. BY520-8 and BY520-9, both having Nemaguard in their lineage, did not differ significantly from Lovell in sucker number. Plums suckered from lateral roots and in some cases formed a thicket of sprouts around the parent tree. Some of the plums that did not sucker also appeared to have good graft compatibility with peach. These individual trees might be useful as semi-dwarfing rootstocks for peaches if they can be vegetatively propagated.

The bacterial canker infection rating differed significantly among rootstocks. BY520-9 and Edible Sloe rootstocks were less susceptible to bacterial canker infection than Lovell after four years (Table 3). In contrast, Bailey, Boone County, Blue Goose, Ferris Strain, and Nemaguard rootstocks were very susceptible to infection. The BY520-9 and Edible Sloe selections that had very low levels of infection in this test also displayed similar resistance to bacterial canker in an earlier ungrafted study (Reighard et al., 1989).

Tree death from PTSL varied significantly among rootstocks (Table 4). BY520-9, BY7446, and Edible Sloe had the lowest PTSL mortality and thereby have promise as potential rootstocks to replace Lovell on PTSL sites. The BY7446 and Edible Sloe plum lines, however, sucker profusely and have some incompatibility problems when used with peach cultivars. Therefore, the most promising rootstock line is BY520-9 which in the past has been a vigorous rootstock with low tree death on severe PTSL sites at the Sandhill Research and Education Center (Reighard et al., 1990b) and the USDA Southeastern Fruit and Tree Nut Research Laboratory at Byron, Georgia (Beckman, 1990). Additional testing of individual seedlots of this rootstock line began in Georgia, South Carolina, and Texas in 1992, and new plantings are planned for 3 other states in 1993 and 1994. The eventual goal of this ongoing research is to select one or several trees to propagate for seed production for the nursery and peach industries.

LITERATURE CITED

Beckman, T.G. 1990. Peach rootstocks: Current research efforts and advancements, Pp. 55-64. In: Proc. 1990 SE/Natl. Peach Conv. Savannah, GA. Jan. 21-23.

Reighard, G.L., D.W. Cain and W.C. Newall, Jr. 1989. Screening *Prunus* germplasm for potential rootstocks for South Carolina replant sites. Acta Hort. 254:287-290.

Reighard, G.L., W.A. Watson, D.C. Coston and J.D. Ridley. 1990a. Survival of own-rooted and budded 'Redhaven' trees on a peach tree short life site. HortScience 25(3):359.

Reighard, G.L., W.C. Newall, Jr. and D.W. Cain. 1990b. Potential new rootstocks for peach tree short life sites. Proc. 5th Stone Fruit Decline Workshop. Biglerville, PA. Sept. 24-26. 4 Pp.

Reighard, G.L. 1990. Effect of orchard floor management on growth and yield of 'Redhaven' peach. Proc. SE Prof. Fruit Workers' Conf. Fletcher, NC. Oct. 16-17. Vol. 5. 7 Pp.

Ritchie, D.F. and C.N. Clayton. 1981. Peach tree short life: A complex of interacting factors. Plant Dis. 65:462-469.

Westcott, S.W. and E.I. Zehr. 1990. Status of *Prunus* rootstocks and selection as hosts for the nematode *Criconemella xenoplax*. Proc. 5th Stone Fruit Decline Workshop. Biglerville, PA. Sept. 24-26.

Zehr, E.I., R.W. Miller, and F.H. Smith. 1976. Soil fumigation and peach rootstocks for protection against peach tree short life. Phytopathology 66:689-694.

Table 1. Julian days until 90% full bloom of 4-year-old 'Redhaven' and 'Springcrest' trees on 12 rootstocks.

Rootstock	Days to 90% full bloom[z]	
	Redhaven	Springcrest
Nemaguard	82 a	71 a
Lovell	82 a	69 ab
Tenn. Natural	82 a	69 ab
BY520-8	80 ab	---
BY520-9	80 ab	68 ab
Bailey	80 ab	---
Edible Sloe	79 bc	69 ab
Boone County	78 bc	69 ab
Ferris Strain	78 bc	68 ab
Transvaal Yel.	78 bc	68 ab
BY7446	77 c	68 ab

(Table 1 Continued)

Blue Goose	76 c	67 b

[z]Mean separation by Waller-Duncan K-ratio T test, P=0.05.

Table 2. Trunk cross-sectional areas (TCSA) for 4-year-old 'Redhaven' and 'Springcrest' peach trees on 12 rootstocks.

Rootstock	Scion Variety			
	Redhaven		Springcrest	
	TCSA[z] (cm^2)	Sprouts	TCSA (cm^2)	Sprouts
BY520-8	119	1.1	---	---
BY520-9	88	2.9	98	1.2
Boone County	83	0.3	37	0.0
Nemaguard	69	2.0	107	7.5
Tenn. Natural	66	0.0	72	0.1
Edible Sloe	57	13.6	56	14.5
BY7446	57	12.5	47	9.4
Ferris Strain	54	0.0	27	0.0
Transvaal Yel.	53	0.0	51	0.1
Lovell	48	0.0	67	0.4
Bailey	39	0.0	---	---
Blue Goose	24	0.3	60	2.0
MSD	37	4.9	37	4.9

[z]Mean separation by Waller-Duncan K-ratio T test, P=0.05

Table 3. Bacterial canker ratings and percent PTSL death for 4-year-old 'Redhaven' and 'Springcrest' peach trees on 12 rootstocks.

	Scion Variety			
	Redhaven		Springcrest	
Rootstock	Bacterial[z,y] canker	%PTSL death	Bacterial canker	%PTSL death
BY520-9	0.0	0	0.2	0
Edible Sloe	0.0	0	0.3	0
BY7446	0.9	15	1.1	10
Transvaal Yel.	1.9	25	1.4	26
BY520-8	2.0	35	---	---
Lovell	2.1	35	2.3	33
Tenn. Natural	2.9	44	2.6	45
Boone County	3.5	67	3.9	58
Ferris Strain	3.6	60	3.5	65
Bailey	3.8	55	---	---
Blue Goose	3.8	44	3.9	50
Nemaguard	4.3	79	4.8	90
MSD	1.4		1.4	

[z]Tree shoots were rated 0-5 with 0=no symptoms, 1=less than 5 twigs infected, 2=more than 5 twigs but no scaffold limbs infected, 3=many twigs and one scaffold with canker, 4=more than one scaffold with canker, and 5=dead from canker.

[y]Mean separation by Waller-Duncan K=ratio T test, P=0.05.

Table 4. Mean trunk cross-sectional area, sprouts, bacterial canker ratings, and % PTSL death for 'Redhaven' and 'Springcrest' combined on 12 rootstocks.

Rootstock	TCSA (cm^2)	Sprouts	Bacterial[z] canker	%PTSL death
BY520-8	119	1.1	2.0	35
BY520-9	92	2.2	0.1	0
Nemaguard	77	3.6	4.5	85
Tenn. Natural	70	0.1	2.7	45
Boone County	68	0.2	3.6	63
Lovell	57	0.2	2.2	34
Edible Sloe	56	14.0	0.1	0
BY7446	52	10.8	1.0	12
Transvaal Yel.	52	0.1	1.6	26
Blue Goose	45	1.0	3.7	47
Ferris Strain	41	0.0	3.5	63
Bailey	39	0.0	3.8	55

[z]Tree shoots were rated 0-5 with 0=no symptoms, 1=less than 5 twigs infected, 2=more than 5 twigs but no scaffold limbs infected, 3=many twigs and one scaffold with canker, 4=more than one scaffold with canker, and 5=dead from canker.

BY520-9, A POTENTIAL NEW ROOTSTOCK FOR THE SOUTHEAST

W.R. Okie[1], T.G. Beckman[1], A.P. Nyczepir[1], G.L. Reighard[2], W.C. Newall, Jr.[2] and E.I. Zehr[2]

INTRODUCTION

In the southeastern United States, peach orchard life is reduced by peach tree short life (PTSL). Trees suddenly collapse and die in the spring, usually in the 3rd to 6th year of life (Ritchie and Clayton, 1981). The disease complex results from an interaction of weather, ring nematode [*Criconemella xenoplax* (Raski) Luc & Raski = *Mesocriconema xenoplax*], and cultural practices such as previous crop, rootstock and pruning date (Sharpe et al., 1989). Tree death is apparently caused by damage to the trunk from cold injury, bacterial canker (*Pseudomonas syringae* pv. *syringae* van Hall) or both. Chemical control of *C. xenoplax* is currently possible with annual postplant nematicides but is not cost-effective. Land with no recent history of peach plantings is getting scarcer and more expensive. 'Lovell' peach is recommended as the rootstock conferring the longest tree life on PTSL sites.

In both field plots and greenhouse pot tests, Lovell often supports lower ring nematode populations than Nemaguard, but both are good hosts (Okie et al., 1987; Sharpe et al., 1989). Therefore, despite the effort involved, field screening for longevity remains the critical test for rootstock selection. Little field screening has been done for tree longevity. C.N. Clayton at N.C. State University made a few rootstock selections in the 1950s and 1960s. F.E. Johnstone of the University of Georgia also made a modest effort in the late 1960s by collecting long-lived local selections and standard stocks. S. Doud of Fort Valley State College continued this work at Byron for a few years in the late 1970s.

Lovell is susceptible to root-knot nematodes (*Meloidogyne* spp.). Where this nematode is common, Nemaguard rootstock is recommended although it is much shorter-lived than Lovell on PTSL sites. None of the other root-knot resistant rootstocks tested in the past, such as Yunnan, Shalil and S-37, have survived well on PTSL sites in the southeastern United States. A rootstock conferring longer tree life, particularly in combination with root-knot nematode resistance, would be of great value to the industry, and is the primary goal of this research project. Preliminary reports of this work have been published (Cain et al., 1986; Okie et al., 1991; Reighard et al., 1989a and 1989b).

MATERIALS AND METHODS

Open-pollinated seed of over 130 diverse lines of peach and plum (diploid *Prunus* hybrids) were collected in 1982, mostly at Byron, GA and planted in a nursery at Clemson, SC. Unbudded trees were tested because of the difficulty of budding so many trees. Five standard lines were also included as rooted cuttings. Commercially budded trees of 'Pekin'/Lovell from North Carolina were added as a standard. About 85 lines produced enough plants to be fully replicated at both sites. Trees were planted in 1983 at the Sandhill Experiment Station, Elgin, SC and at the USDA facility at Byron, GA. The USDA planting consisted of 8 randomized blocks each containing a 6-tree plot of most lines. The site, a Faceville fine sandy loam, had a history of PTSL and had last been in peaches 2 years earlier. The SC site consisted of 6 randomized blocks of 8 trees each on a site long planted to peaches. Soil type was Lakeland fine sand. Tree spacing was 0.6 m within the row and 4-5 m between rows. Preplant ring nematode populations were obtained in November 1982 and ranged from 50-360/150 cm^3 soil.

Trees were unthinned, and unsprayed except for peachtree borer (*Synanthedon* spp.) trunk sprays each fall. Trees were minimally pruned of lower limbs when young, then left unpruned except for being hedged in fall (typically Dec.) of 1985, 1986, 1988, and 1990 at Byron and Fall 1989 at Elgin. Each fall through 1986 all plots in 4 selected blocks at Byron were sampled for ring

[1]USDA-ARS, Southeastern Fruit and Tree Nut Research Laboratory, Byron, GA 31008

[2]Clemson University, Clemson, SC 29634

nematodes. Two probes per tree were obtained from the inner four of six treatment trees and composited. Nematodes were extracted from 100 cm^3 soil samples using elutriation (Byrd et al., 1976) combined with sugar-centrifugal flotation (Jenkins, 1964) and counted.

Survival data was analyzed using analysis of variance (SAS Institute, 1987). Transformation was ineffective in reducing the modest correlation between means and variances therefore no transformation was used. Means are based on plot means and separated using Waller-Duncan *k*-ratio test. Lines lacking substantial replication were excluded from the Waller-Duncan test. Each spring (and fall of 1983-86) dead trees were inspected and the cause of death determined by digging around the roots. A few trees died from transplant shock, crown gall or unknown causes. When signs of oak root rot (*Armillaria tabescens* Scop.:Fr.) were seen on the roots it was designated the cause of death. This disease is endemic in the Southeast and also causes substantial tree losses particularly in heavier soils. Typical symptoms of PTSL were trunk cambial browning ending at the soil line and healthy roots, often with rootstock suckers appearing from below the ground. In South Carolina PTSL symptoms often included bacterial canker.

RESULTS AND DISCUSSION

Tree losses due to PTSL in Georgia were highest in 1986 and 1987 (Fig. 1). Tree losses were higher in years following fall pruning (hedging). Early losses were higher in Georgia than South Carolina (Fig. 1). Correlations of nematode counts and tree death were low (Georgia data not shown; Reighard et al., 1989a) perhaps because the sample did not accurately reflect the true population under the trees. Oak root rot was not a cause of tree death in South Carolina. Death from oak root rot at Byron was fairly constant until tree numbers had declined in 1990. By 1991 only 11% of the original 4,885 trees survived at Byron compared to 30% of the original 5,366 at Elgin.

The large variation in mean survival (data not shown) can be attributed to environmental, nematode population density and genetic causes. The large degree of variation in the initial ring nematode population density in the test plot was attributed to tree row influence resulting from a prior planting. Higher nematode counts were detected in soil taken closest to old tree rows. It is therefore important that one consider such an effect when establishing a new test orchard on an old site when monitoring nematode density and tree survival. Tree losses at Byron due to oak root rot confound the losses due to PTSL. However, PTSL is more common in years 3 to 6 of an orchard whereas root rot tends to kill trees later. Some trees may have died from both pathogenic agents.

Performance of standard rootstocks are shown in Figure 1. Results closely resemble those reported for budded trees in the southeastern United States (Dozier et al., 1984; Ritchie and Clayton, 1981; Sharpe et al., 1989) Lovell and Halford survived longest, followed by Nemaguard, with Siberian C surviving the shortest period of time.

Tree losses were similar for rooted cuttings or seedlings of Nemaguard, Lovell and Halford. 'Pekin'/Lovell trees survived slightly better than unbudded Lovell seedlings. 'Redglobe' rooted cuttings did not survive as well as 'Redglobe' seedlings. Many of the poorer surviving lines were root-knot nematode resistant lines.

Reighard et al., (1989a) found a low negative correlation (-0.43) between a lines vegetative chilling requirement and tree survival for 28 selected lines in the Elgin planting. Trees of some of the lines with the lowest chilling requirements such as 'Killiekrankie' were killed in 1985 following an unusually cold winter. FLA9-4, a selection from the University of Florida rootstock breeding program, was the best surviving low-chilling line. On the other hand, comparatively high-chilling, cold-hardy rootstocks such as Chui Lum Tao, Tzim Pee Tao, and Siberian C survived poorly. Neither scion

cold hardiness nor chilling requirement appears to determine susceptibility to cold injury from PTSL.

Use of unbudded seedlings or cuttings planted at high density appears to be a low-cost way to test a large number of genotypes.

B594520-9 was the top survivor at both sites (Fig. 1). However statistical superiority to Lovell was not evident until 1989, 6 years after planting. In a follow-up planting consisting of budded trees at commercial spacing on a severe PTSL site in South Carolina (Reighard et al., 1991), BY520-9 (bulked seed from surviving seedlings of B594520-9) is surviving substantially better than Lovell in the 4th year. Preliminary results also indicate selections of B594520-9 exhibit root-knot nematode resistance comparable to Nemaguard, as expected based on its parentage which traces back to S-37 and Nemaguard. B594520-9 was a remnant of the root-knot nematode resistant rootstock development program (Fig. 2) carried on by USDA and de-emphasized after the introduction of Nemaguard in 1959. The source and nature of the factors resulting in greater longevity for B594520-9 and its surviving seedlings, collectively known as BY520-9, are unknown, but may have resulted from outcrossing that occurred during the several cycles of open pollination. Unfortunately the original selection B594520-9 no longer exists. A grower trial of several selections of BY520-9 is underway at several sites in the Southeast.

LITERATURE CITED

Byrd, D.W., Jr., K.R. Barker, H. Ferris, C.J. Nusbaum, W.E. Griffin, R.H. Small and C.A. Stone. 1976. Two semi-automatic elutriators for extracting nematodes and certain fungi from soil. J. Nematol. 8:206-212.

Cain, D.W., E.I. Zehr, W.R. Okie and A.P. Nyczepir. 1986. Screening of Prunus germplasm for resistance to *Criconemella xenoplax* and peach tree short life. HortScience 21:710.

Dozier, W.A., Jr., J.W. Knowles, C.C. Carlton, R.C. Rom, E.J. Arrington, E.J. Wehunt, U.L. Yadava, S.L. Doud, D.F. Ritchie, C.N. Clayton, E.I Zehr, C.E. Gambrell, J.A. Britton and D.W. Lockwood. 1984. Survival, growth, and yield of peach trees as affected by rootstocks. HortScience 19:26-30.

Jenkins, W.R. 1964. A rapid centrifugal flotation method for separating nematodes from soil. Plant Dis. Rep. 48:692.

Johnstone, F.W., Jr. 1971. A preliminary report on testing peach rootstocks on the site of a "declined" peach orchard in Fort Valley. Proc. 30th Annu. Conv. Natl. Peach Council Pp. 77-80.

Okie, W.R., T.G. Beckman and A.P. Nyczepir. 1991. *Prunus* rootstock germplasm with increased longevity in the southeastern U.S. HortScience 26:710.

Okie, W.R., A.P. Nyczepir and C.C. Reilly. 1987. Screening of peach and other Prunus species for resistance to ring nematode in the greenhouse. J. Amer. Soc. Hort. Sci. 112:67-70.

Reighard, G.L., D.W. Cain and W.C. Newall, Jr. 1989a. Relationship of chilling requirement in *Prunus persica* (L.) Batsch to peach tree short life. Fruit Var. J. 43:121-125.

Reighard, G.L., W.C. Newall, Jr. and D.W. Cain. 1989b. Screening *Prunus* germplasm for potential rootstocks for South Carolina replant sites. Acta Hort. 254:287-290.

Reighard, G.L., W.C. Newall, Jr., E.I. Zehr, W.R. Okie and T.G. Beckman. 1991. Short life mortality of 'Redhaven' and 'Springcrest' peach on selected rootstocks. Proc. SE Prof. Fruit Workers Conf. Vol. 6, 8 Pp.

Ritchie, D.F. and C.N. Clayton. 1981. Peach tree short life: A complex of interacting factors. Plant Dis. 65:462-469.

SAS Institute Inc. 1987. SAS/STAT guide for personal computers. Version 6 edition. Cary, NC.

Sharpe, R.R., C.C. Reilly, A.P. Nyczepir and W.R. Okie. 1989. Establishment of peach in a replant site as affected by soil fumigation, rootstock, and pruning date. Plant Dis. 73:412-415.

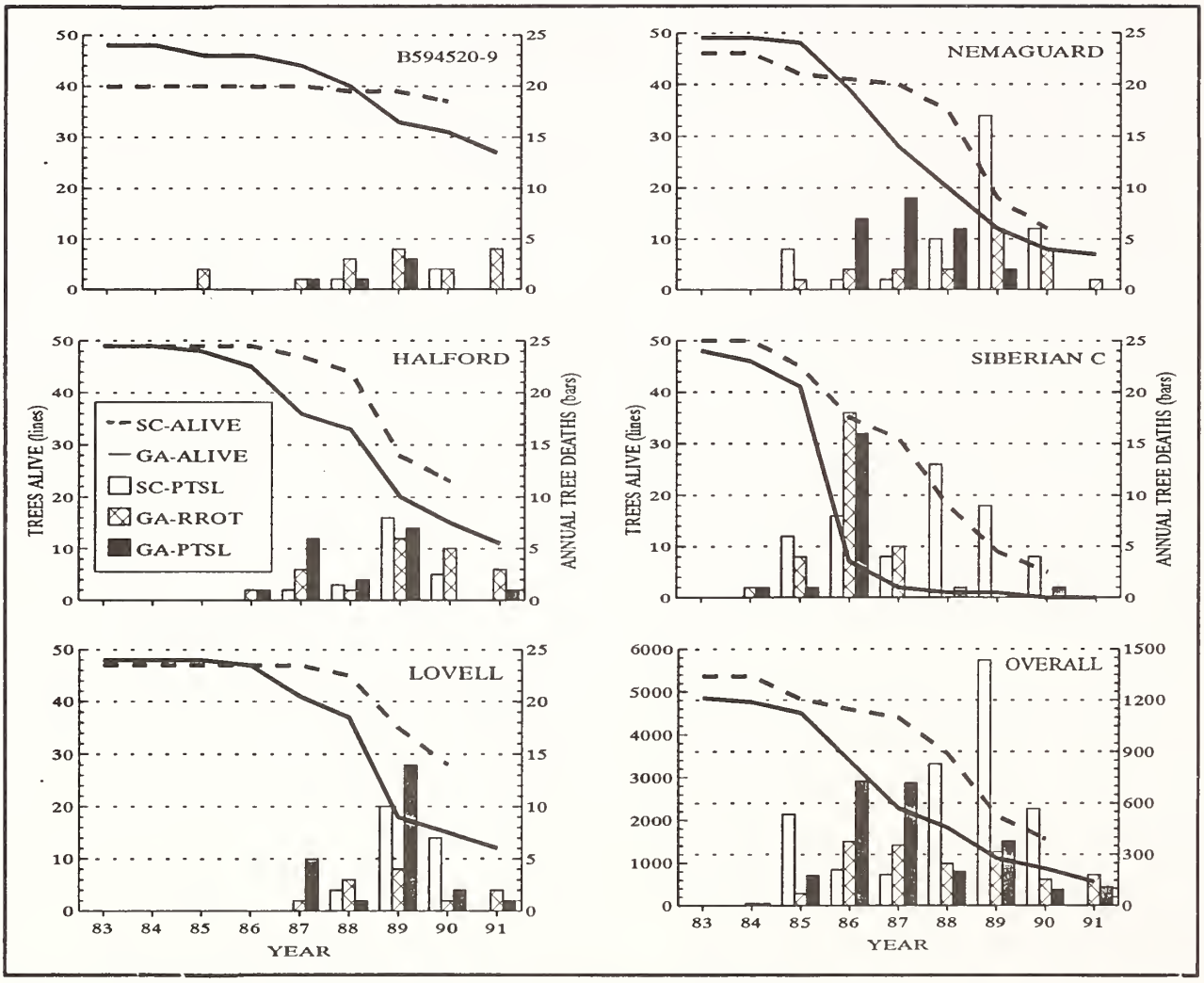


Figure 1. Number of trees alive and annual tree losses by cause overall and for selected peach rootstocks. Field screening conducted in Byron, Georgia and Elgin, South Carolina 1983–1991. All South Carolina deaths due to short life (PTSL). Some Georgia mortality also caused by oak root rot (RROT).

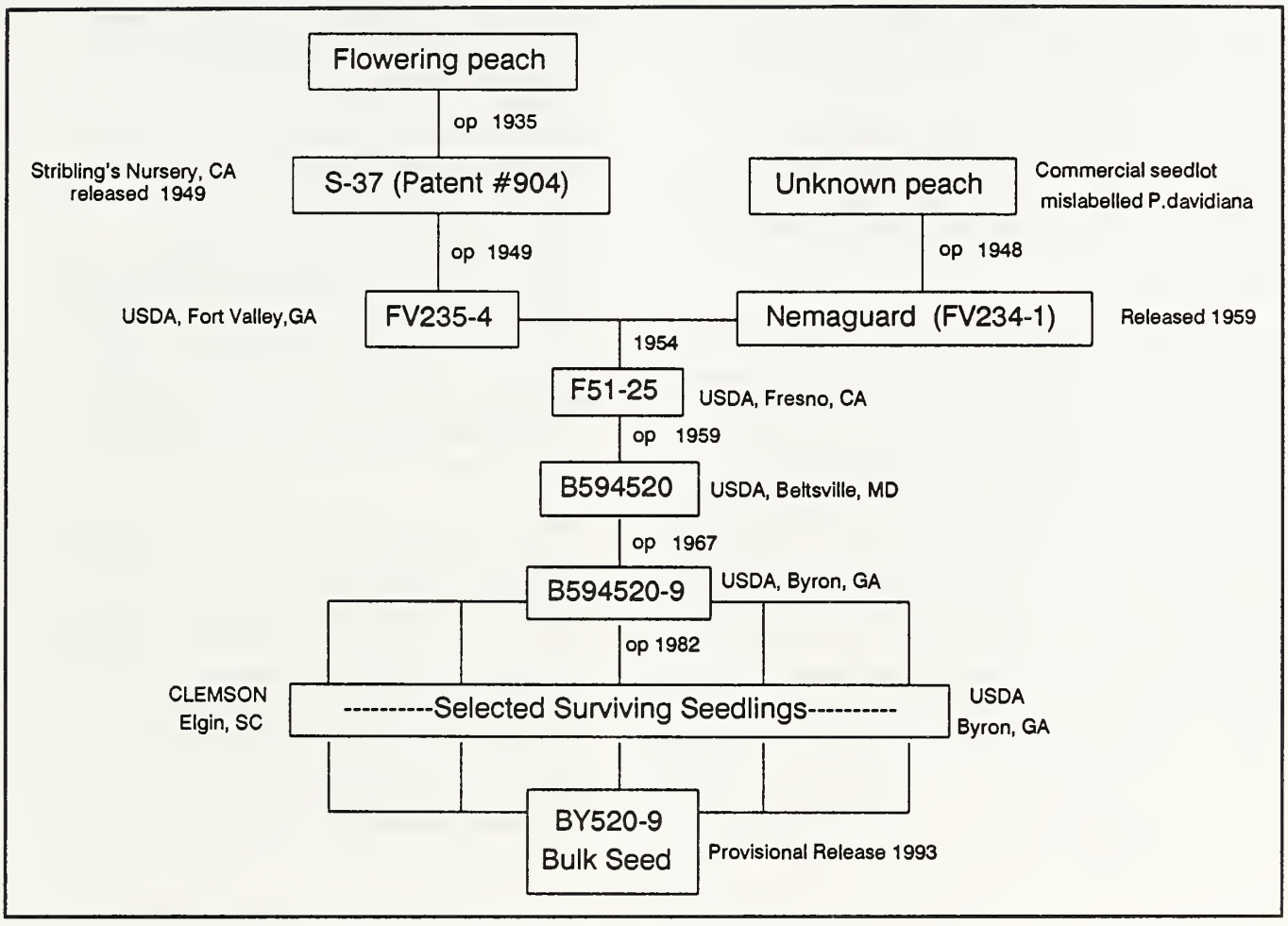


Figure 2. Pedigree of BY520-9 rootstock. Open-pollinated generations designated "op".

TECHNIQUES FOR SCREENING *PRUNUS* ROOTSTOCKS FOR RESISTANCE TO *PRATYLENCHUS VULNUS*

C.A. Ledbetter[1]

The root lesion nematode (*Pratylenchus vulnus* Allen and Jensen) is one of three phytoparasitic nematodes considered economically important in stone fruit orchards throughout the world. Damage caused by this pest is most typical in replant situations, but yield reductions have been documented in mature Japanese plum orchards (McKenry, 1989). 'Nemaguard' and 'Lovell' are good hosts for this nematode as are other common peach rootstocks.

After the elimination of 1,2-dibromo-3-chloropropane (DBCP) as a postplant treatment for orchard nematode control, *P. vulnus* became a more important pest. Commodity Boards such as the Almond Board of California, California Prune Board and California Tree Fruit Agreement actively supported research aimed at solving the root lesion nematode problem. Since 1987 these Boards have contributed to the Agricultural Research Service rootstock breeding and evaluation effort in Fresno, CA. The overall goal of the program is to identify candidate rootstock germplasm that are resistant to the attack of root lesion nematode.

Pratylenchus vulnus has a broad host range and is widely distributed throughout temperate fruit growing regions. There have been reports of various *Prunus* accessions being non-hosts to this pest (Day and Serr, 1951; LaMassese, 1975). Since a large research collection of *Prunus* existed at the ARS facility in Fresno, CA, efforts were put forward to establish efficient screening techniques and to identify resistant rootstock materials. Culver et al. (1989) should be credited with the development of an effective greenhouse screen capable of identifying *Prunus* accessions resistant to *P. vulnus*.

[1]Research Geneticist, USDA-ARS, Horticultural Crops Research Laboratory, Postharvest Quality and Genetics, 2021 S. Peach Avenue, Fresno, CA 93727-5951

Since 1988, over 150 *Prunus* accessions have been screened in the greenhouse for host suitability to *P.vulnus*. At least nine new resistant accessions have been identified. These candidate rootstocks have been screened repeatedly and *P. vulnus* does not appear to reproduce on their root systems. Other candidate rootstocks appear to 'tolerate' nematode reproduction and support increasing numbers of nematodes while not producing significantly less growth than the uninoculated control plants. Trudgill (1991) points out the danger of using these types of individuals rather than truly resistant germplasm. Tolerant individuals may become susceptible after a certain critical population level is attained.

Hands-on experience with *Prunus* candidate rootstocks under nematode infected and uninfected conditions indicate that there is no reliable visual evidence of *P. vulnus* presence/damage to the root system. Root lesions appear to be an unreliable indicator of the nematode's presence. This being the case, uninoculated 'control' plants of each candidate rootstock accession must always be grown along with nematode-inoculated plants to serve as a comparison. Other important production factors associated with the greenhouse screening technique are as follows:

1. Soil Medium - A stem sterilized mixture of 3 sand:1 sandy loam soil is used. Accessions being screened, whether seed or clonally propagated, are grown in 730 cm^3 pots.

2. Production of Inoculum - *P. vulnus* is effectively reared on young, susceptible seed-propagated peach germplasm. Three to six months may be required between initial inoculation of clean cultures and inoculum harvest. Planning is essential to match inoculum availibility with the proper inoculation period for candidate rootstocks.

3. Inoculum Level and Duration of Screen - Candidate rootstocks are inoculated with

150 vermiform nematodes per plant. The screen operates for a total of 150 days.

This standard inoculation has increased to over 35,000 extractable nematodes during the growth period for susceptbile germplasm such as *Prunus spinosa*.

4. Harvest - Shoot and root fresh weights were obtained at harvest. Root systems are mist extracted (Lownsbery and Serr, 1963) for a standard five day period, and then quantified. Within rootstock accessions, ANOVA are run between inoculated and control plants to compare growth parameters.

5. Logistics - Eight plants of both nematode infected and uninfected controls are being used for each candidate rootstock being screened. This may be considered a balance between precision, space availability and cost. Five to 10 candidate rootstocks may be inoculated at a single date. This ensures that no more than 160 plants will be harvested in a single day. We have observed this to be the maximum number of plants that two reasonable persons can expect to handle, and is also the maximum capacity of the mist extraction system.

A variety of different propagules have been used in the root lesion nematode screen. Clonal materials have been obtained from micropropagation as well as hardwood and softwood cuttings. Stratified seed are typically used from field grown peach candidate rootstocks. Results obtained in the screen can be dramatically different depending on the propagule used. While clonal materials of 'Deep Purple' are completely resistant to *P. vulnus*, seed-propagated plants from this accession rear an average of 92 nematodes per gram root (FW) at 150 days past inoculation.

From an evaluation standpoint, we have identified new sources of resistance to *P. vulnus* within the *Prunus* genera. These resistant individuals will become successful rootstocks only if they meet other specific criteria. Graft compatibility and fruit/nut yield are of utmost concern to the various Commodity Boards. Field trials have commenced that will demonstrate whether or not these criteria can be met. Similarly, the resistance of these candidate rootstocks to root-knot nematode (*Meloidogyne* spp.) must also be assessed.

Hybridizations have been performed between root lesion nematode resistant materials and commercial root-knot resistant rootstocks. The first of these populations should begin to fruit during the 1993 season. We would like to determine, from seed produced on these trees, whether the resistance to root lesion nematode is inherited as a dominant characteristic. This knowledge is pertinent to the next round of breeding/progeny screening.

We are continuing the quest to identify new root lesion nematode resistant candidate rootstocks. The effort is now being concentrated in peach germplasm due to it's superior compatibility with most scion cultivars. We are also concerned with improving the efficiency of our screening technique. The fact that we have identified both resistant and susceptible germplasm now allows us the opportunity to develop in-vitro screening techniques. Currently, we have *P. vulnus* reproducing on susceptible *Prunus* roots under sterile conditions. In the future, we are hoping to identify a discerning criteria that would allow us to differentiate between resistant and susceptible materials in a shorter period of time than the current greenhouse technique.

Day and Serr (1951) evaluated candidate rootstocks three years after trees had been challenged with *P. vulnus* under infested field conditions. The greenhouse screening technique developed by Culver et al. (1989) requires 150 days between inoculation and harvest. The greenhouse technique could be regarded as a major improvement in screening efficiency. However, it has been demonstrated that *P. vulnus* requires only 26 days to complete it's life cycle when cultured on carrot

discs at 25 C (Chitambar and Raski, 1985). Therefore, it appears that there is still room for improving the screening technique and identifying root lesion resistant germplasm in a shorter, more cost-effective manner.

LITERATURE CITED

Chitamber, J.J. and D.J. Raski. 1985. Life history of *Pratylenchus vulnus* on carrot discs. J. Nematol. 17(2):235-236.

Culver, D.J., D.W. Ramming and M.V. McKenry. 1989. Procedures for field and greenhouse screening of *Prunus* genotypes for resistance and tolerance to root lesion nematode. J. Amer. Soc. Hort. Sci. 114(1):30-35.

Day, L.H. and E.F. Serr. 1951. Comparative resistance of rootstocks of fruit and nut trees to attack by root lesion or meadow nematode. Proc. Amer. Soc. Hort. Sci. 57:150-154.

LaMassese, S. 1975. Tests D'hotes de quelques porte-greffe et varietes a l'egard de *Pratylenchus vulnus* Allen et Jensen. Comptes Rendus des Seances de l'Academie d'Agriculture de France 61(17):1088-1095.

Lownsbery, B.F. and E.F. Serr. 1963. Fruit and nut tree rootstocks as hosts for a root lesion nematode, *Pratylenchus vulnus*. Proc. Amer. Soc. Hort. Sci. 82:250-254.

McKenry, M.V. 1989. Damage and development of several nematode species in a plum orchard. Applied Agr. Res. 4(1):10-14.

Trudgill, D.L. 1991. Resistance to and tolerance of plant parasitic nematodes in plants. Annu. Rev. Phytopath. 29:167-192.

COLD HARDINESS AND FALL NONSTRUCTURAL CARBOHYDRATE RESERVES IN ONE-YEAR-OLD SWEET CHERRY TREES

M.A, Longstroth[1], R.T. Fernandez[1], R.L. Perry[2] and J.A. Flore[3]

ABSTRACT

'Emperor Francis' sweet cherry on mazzard and mahaleb rootstocks were drought stressed in a rain exclusion shelter at the Kellogg Biological Station. Half the plants were irrigated with 2 liters of water per day. The remaining trees were subjected to 2 drought cycles, of approximately one month duration with no irrigation. A 10 day recovery period with irrigation at 2 liters of water per day, separated the 2 drought cycles. In late September, the current season's growth of mazzard rooted scions was hardier than that on mahaleb rootstocks. In mid-October, the apical portion of the current season's growth was more tender than other portions of the stem. Small roots (3-4 mm dia.) did not withstand temperatures below -4 C. Mazzard rooted scions were again hardier and xylem tissue was more hardy than phloem. Nonstructural carbohydrate content was determined from the October samples. Sucrose was the major soluble carbohydrate. High levels of sorbitol were found in mazzard roots. Sorbitol levels were higher in drought stressed plants. Raffinose and stachyose were most abundant in the current season's growth. Mahaleb rootstock stored large amounts of starch in the root shank. No correlations were found between carbohydrate levels and cold hardiness.

INTRODUCTION

Unseasonably cold weather in the late fall or early winter can cause tree death due to freezing injury. When death does not occur, winter injury often allows secondary infection by *Cytospora* and/or *Pseudomonas*. The ability of young trees to withstand winter injury influences their longevity. Rootstocks have been shown to influence cold hardiness in cherry scions (Howell and Perry, 1990). Early defoliation reduced the cold hardiness of 'Montmorency' tart cherry (Howell and Stackhouse, 1973). Shading reduced cold hardiness and growth in one-year-old tart cherry (Flore et al., 1983). Severe drought stress can reduce the amount of stored carbohydrates by reducing photosynthesis (Wample, 1982). Mild drought stress in early fall, to induce hardening, is a common practice in the Pacific Northwest (Proebsting, 1982). Osmotic adjustment in response to drought stress may enhance the development of cold hardiness (Grierson et al., 1982). Soluble carbohydrates have been implicated in resistance to freezing damage and stress (Lineberger and Steponkus, 1980). The purpose of this study was to determine the carbohydrate content of young cherry trees after exposure to mild drought stress, and to determine if mild drought stress hindered or enhanced acclimation.

MATERIALS AND METHODS

'Emperor Francis' sweet cherry on mazzard and mahaleb rootstocks were drought stressed in a rainshelter at the Kellogg Biological Station (Martin et al., 1988). Half the plants were irrigated with 2 liters of water per day. The remaining trees were subjected to 2 drought cycles, each of approximately one month duration with no irrigation. A 10 day recovery period with irrigation at 2 liters of water per day, separated the 2 drought cycles. Shoot and leaf growth was monitored twice a week. Soil moisture and leaf gas exchange were monitored at the same interval. The overall purpose of the experiment was to determine which physical or physiological measurements were the best indicators of drought stress and if there was a differential rootstock response. The drought stress imposed was sufficient to cause shoot growth to cease during the initial stress period, but did not cause

---

[1]Graduate Assistant, Department of Horticulture, Michigan State University, East Lansing, MI 48824-1325

[2]Associate Professor, Department of Horticulture, Michigan State University, East Lansing, MI 48824-1325

[3]Professor, Department of Horticulture, Michigan State University, East Lansing, MI 48824-1325

defoliation. The final drought stress period ended on September 7, 1991.

On September 27, 1991, shoots of the current season's growth were removed from 4 trees of each treatment and brought to campus in plastic bags. Each shoot was cut into 3 lengths of approximately equal size corresponding to the apical, median and basal portions of the shoot. A one cm portion from the middle of each region was removed. These small one cm samples were frozen and the water extracted by freeze drying, to determine tissue water content.

On October 17, 1991, 4 trees of each treatment, including roots were dug up, placed in a plastic bag and returned to campus. The current year's growth was sampled and divided as before. The remainder of the scion consisting of a one-year-old stub approximately 10-15 cm long was subsampled for water content determination and then split longitudinally into quarters for use in the cold hardiness assay. The rootstock shank, that portion of the rootstock below the graft union and above the soil line, was treated in a similar manner. Lengths of roots approximately 2-4 mm in diameter were also used in the assay. The dried subsamples used to determine tissue water contents were later used to determine tissue carbohydrate levels.

The stem portions from each rootstock, irrigation treatment and stem position combination were pooled. The shoots were cut into 5-10 cm portions. Single sections from each scion, rootstock, irrigation treatment, and shoot position were placed on tape strips and numbered for later identification. Each tape was placed on moist cheesecloth and wrapped with aluminum foil. A copper-constantan thermocouple was inserted into a stem located near the center of the tape, and the foil package rolled into a cylinder. The packets were held overnight at -3 C, in a freezer with a programmable temperature control. Three packets were removed in the morning at -3 C and the freezer's temperature lowered 3 C per hour. Three packets of stems were removed at -6, -9, -12, -15, -18, -21, and -24 C. The packets were removed when the packet's thermocouple indicated the desired temperature had been reached. The packets were then held overnight at 5 C in a cold room. The foil was removed and the stems were stored in a saturated atmosphere at room temperature for 9 days, allowing visual browning symptoms to develop. Phloem and xylem tissues were visually rated as to tissue browning, discolored tissues were assumed to have died due to freezing injury. Healthy stem tissue was white to green. Live roots were white, dead roots were brown or clear. The T_{50} (lethal temperature which kills 50% of the tissues) was determined using the technique of Bittenbender and Howell (1974). The T_{50} data was analyzed as a completely randomized design using the ANOVA procedure in SAS. The experimental designs used in the analyses were a 2 x 2 x 2 x 2 (rootstock, irrigation treatment, plant position and tissue) factorial for the September 27 date and a 2 x 2 x 5 x 2 for October 17.

The pooled subsamples from each rootstock, treatment, position combination used to determine water content were also used to determine tissue carbohydrate levels. Xylem and phloem were not separated in these samples. These samples were lyophilized, weighed and ground in a Wiley mill to pass through a 40-mesh screen. Two 100 mg subsamples were taken from each ground sample and analyzed for soluble carbohydrate and starch content. The subsamples were extracted with 80% ethanol. The pellet was evaporated to dryness and used to determine starch content. Starch in the pellet was measured using the method of Roper et al. (1988). The supernatant was mixed with water and chloroform to remove chlorophyll from the sample extract. The clear aqueous phase was removed and evaporated to dryness.

Soluble carbohydrates were separated and quantified using a Dionex 4000i HPLC system, equipped with a gradient pump, Carbopac PA1 column, autosampler and pulsed amperometric detector. The column was eluted with 16 MOhm water and 200mM NaOH, which were continuously degassed with helium during the analysis. A combination of gradient and isocratic elution was used: 1. prior to injection, the column was

eluted with 65% water and 35% NaOH; 2. at time= 0 min, the sample was injected and the gradient pump was then adjusted to 75% water and 25% NaOH by time = 0.1 min, this ratio was maintained until time = 1.5 min; 3. from time = 1.5 min to 9.0 min the gradient was adjusted to 0% water and 100% NaOH; 4. from time = 9 min to 23 min the column was isocratically eluted with 100% NaOH. The flow rate of the eluant was held constant at 1 ml/min. The sample was prepared for HPLC analysis by adding 1 ml of 16 MOhm water, to the dried sugar residue. Two separate sample dilutions (1:25) were analyzed from each subsample. Soluble carbohydrates were identified and quantified by their retention times and peak areas.

RESULTS

Rootstock was the only significant factor influencing cold hardiness, in September. Tissue of mazzard rooted scions were generally hardier than the corresponding tissue from mahaleb rooted scions. Figure 1 contains the T_{50} values for September 27. Drought stress, shoot position and tissue type did not significantly affect cold hardiness. On October 17, rootstock, position and tissue type were all significant, but drought stress was not (Fig. 2). Mazzard rooted scions were again hardier than those on mahaleb roots. Rootstock shank, one-year-old trunk and the basal portion of the current season's growth were more hardy than the apical portion of the shoot. Roots were much more tender than the above ground portions of the stem. Xylem tissues were usually hardier than the corresponding phloem tissues. But the phloem and xylem of the rootstock shanks and small roots were equally hardy. Drought stress alone did not significantly effect cold hardiness. But drought stressed trunk xylem was hardier than the trunk xylem of the irrigated controls. Figure 3 contains the T_{50} values for October 17.

Figure 4 shows the levels of starch, sucrose, total soluble carbohydrates and total nonstructural carbohydrates in different cherry tissues on October 17. Starch levels were fairly uniform in the scion with levels of about 35 to 40 mg·g dry wt. Very high levels of starch were found in mahaleb rootstock shanks.

Irrigated mahaleb shanks had more starch than drought stressed mahaleb. Shanks of irrigated mazzard controls had intermediate levels of starch while the drought stressed mazzard starch levels showed no increase over stem levels. Sucrose was the most abundant soluble sugar accounting for one third to a half of the total soluble carbohydrates. Sucrose levels were fairly constant in all plant tissues. Figure 5 shows tissue levels for minor soluble carbohydrates. Tissue levels for these carbohydrates varied greatly according to sample position in the plant. Sorbitol levels were higher in roots than stems. Stem sorbitol levels were higher in the drought stressed plants. Inositol was the least abundant soluble carbohydrate. Inositol levels were also higher in the roots than in the stems. Glucose and fructose levels were similar within a given stem position but varied along the stem. Glucose levels were generally higher than fructose levels. Drought stressed mahaleb rootstock shanks had very high levels of glucose and fructose. Mazzard rooted scions had similar levels of glucose and fructose across stems and roots. The oligosaccharides raffinose and stachyose were most abundant in the current seasons growth and the tissue concentrations declined down the shoot with the lowest levels in the roots.

DISCUSSION

The lack of differences among tissue cold hardiness on September 27 indicates that acclimation was not well advanced on this date. Cold hardiness values in peach (Flore et al., 1983) indicate that the apical portion of the shoots is initially more hardy than basal portions. Later in the season, this trend is reversed with the basal portion being more hardy. The October 17 sample indicates that this reversal in stem and tissue hardiness had taken place during the previous 3 weeks. The lack of a well defined enhancement of cold hardiness due to the mild drought stress, and the small increment

of increased hardiness gained do not encourage the use of mild drought stresses as a cultural practice to increase early winter cold hardiness. The low cold hardiness of the root systems points to the importance of practices which would reduce soil freezing, such as late irrigations and mulches.

No correlations were found between tissue cold hardiness and levels of specific or total soluble carbohydrates. Tissues of the apical shoot and the small roots had high levels of soluble carbohydrates but were also the least cold hardy tissues. High levels of sorbitol were found in the roots, and drought stressed tissues had increased levels of sorbitol compared to irrigated controls. These high levels of sorbitol are probably due to osmotic adjustment in the roots and drought stressed tissues. Ranney et al. (1991) demonstrated that sorbitol is the major osmolyte involved in osmotic adjustment in cherries. Keller and Loescher (1989) demonstrated that sorbitol was the major soluble carbohydrate in sweet cherry for most of the growing season, but that sucrose became the major soluble storage carbohydrate in the fall. The high levels of sucrose found in all tissues in this study support this. Starch was the major storage carbohydrate. Stem tissues of the scion had relatively constant levels of starch. The rootstock shank appeared to be a major storage organ for mahaleb rooted scions. Carlson and Yu (1969) found increased levels of starch in the bark below the graft union of Napoleon sweet cherries grafted on mahaleb compared to the same scion grafted on mazzard. The irrigated mazzard root shank also stored increased amounts of starch in the rootstock shank. Carlson and Yu (1969) suggested that the increased starch content of the rootstock may have been a symptom of graft incompatibility or the rootstock inability to metabolize all the photoassimilate translocated from the scion. Keller and Loescher (1989) demonstrated that large amounts of carbohydrates are stored in the roots of 'Bing' sweet cherry on mazzard rootstock, and that these reserves are used to fuel the growth in early spring. The reduced levels of starch in the drought stressed rootstock shanks may represent the allocation of photoassimilate to root growth. The very high levels of glucose and fructose in the irrigated mahaleb rootstock shanks may be a consequence of the active conversion of sorbitol to starch via fructose and glucose. The high levels of raffinose and stachyose were found in new growth, Keller and Loescher (1989) suggested that raffinose may function as a storage carbohydrate. Stachyose levels were lower than raffinose in the irrigated shoots but stachyose levels were increased to levels similar to raffinose drought stressed shoots. This suggests that stachyose may play a role in osmotic adjustment.

LITERATURE CITED

Bittenbender, H.C. and G.S. Howell, Jr. 1974. Adaptation of the Spearman-Karber method for estimating the T_{50} of cold stressed flower buds. J. Amer. Soc. Hort. Sci. 99:187-190.

Carlson, R.F. and K. Yu. 1969. Starch content in cherry stems near loci of graft, banding and scoring. HortScience 4:246-248.

Flore, J.A., G.S. Howell and C.E. Sams. 1983. The effect of artificial shading on cold hardiness of peach and sour cherry. HortScience 18:321-322.

Grierson, W., J. Soule and K. Kawada. 1982. Beneficial aspects of stress. Hort. Rev. 4:247-271. AVI, Westport, Conn.

Howell, G.S. and R.L. Perry. 1990. Influence of cherry rootstock on the cold hardiness of twigs of the sweet cherry scion. Sci. Hort. 43:103-108.

Howell, G.S. and S.S. Stackhouse. 1973. The effect of defoliation time on acclimation and dehardening in tart cherry (*Prunus cerasus* L.). J. Amer. Soc. Hort. Sci. 98:132-136.

Keller, J.D. and W.H. Loescher. 1989. Nonstructural carbohydrate partitioning in perennial parts of sweet cherry. J. Amer. Soc. Hort. Sci. 114:969-975.

Lineberger, R.D. and P.L. Steponkus. 1980. Cryoprotection by glucose, sucrose and raffinose to chloroplast thylakoids. Plant Physiol. 65:298-304.

Martin, E.C., J.T. Ritchie, S.M. Reese, T.L. Loudon and B. Knezek. 1988. A large-area lightweight rainshelter with programmable control. Trans. Amer. Soc. Agr. Eng. 31:1440-1444.

Proebsting, E.L., Jr. 1982. Water management practices and their effects on fruit trees, Pp. 133-151. In: R.B. Tukey (ed.) Tree Fruit Water Management and Irrigation. Shortcourse Proc. Wash. State Coop. Ext. Pullman, Wash.

Ranney, T.G., N.L. Bassuk and T.H. Whitlow. 1991. Turgor maintenance in leaves and roots of 'Colt' cherry trees (*Prunus avium* x *psuedocerasus*) in response to water stress. J. Hort. Sci. 66:381-387.

Roper, T.R., J.D. Keller, W.H. Loescher and C.R. Rom. 1988. Photosynthesis and carbohydrate partitioning in sweet cherry: Fruiting effects. Physiol. Plant. 72:42-47.

Wample, R.L. 1982. Water stress in fruit trees, Pp. 95-107. In: R.B. Tukey (ed.) Tree Fruit Water Management and Irrigation. Shortcourse Proc. Wash. State Coop. Ext. Pullman, Wash.

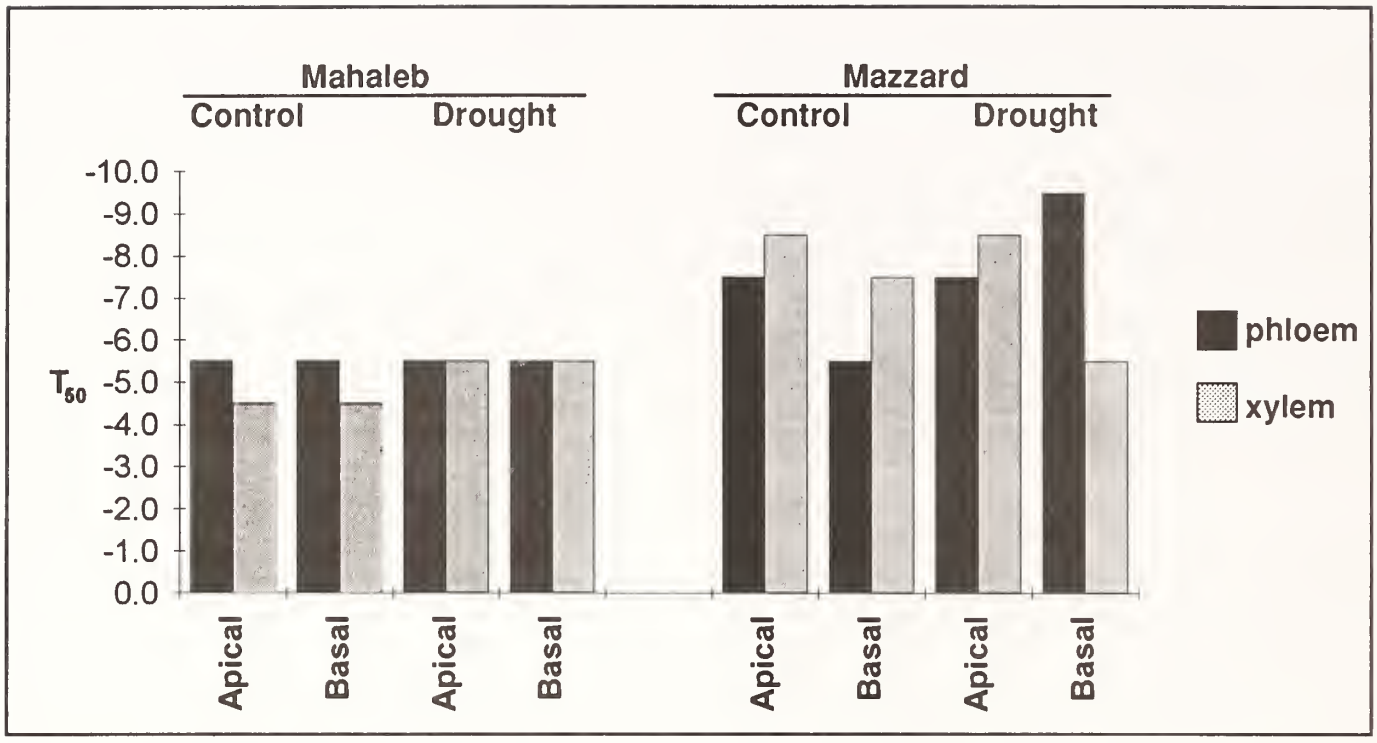


Figure 1. T_{50} cold hardiness values for tissues collected on September 27, 1991.

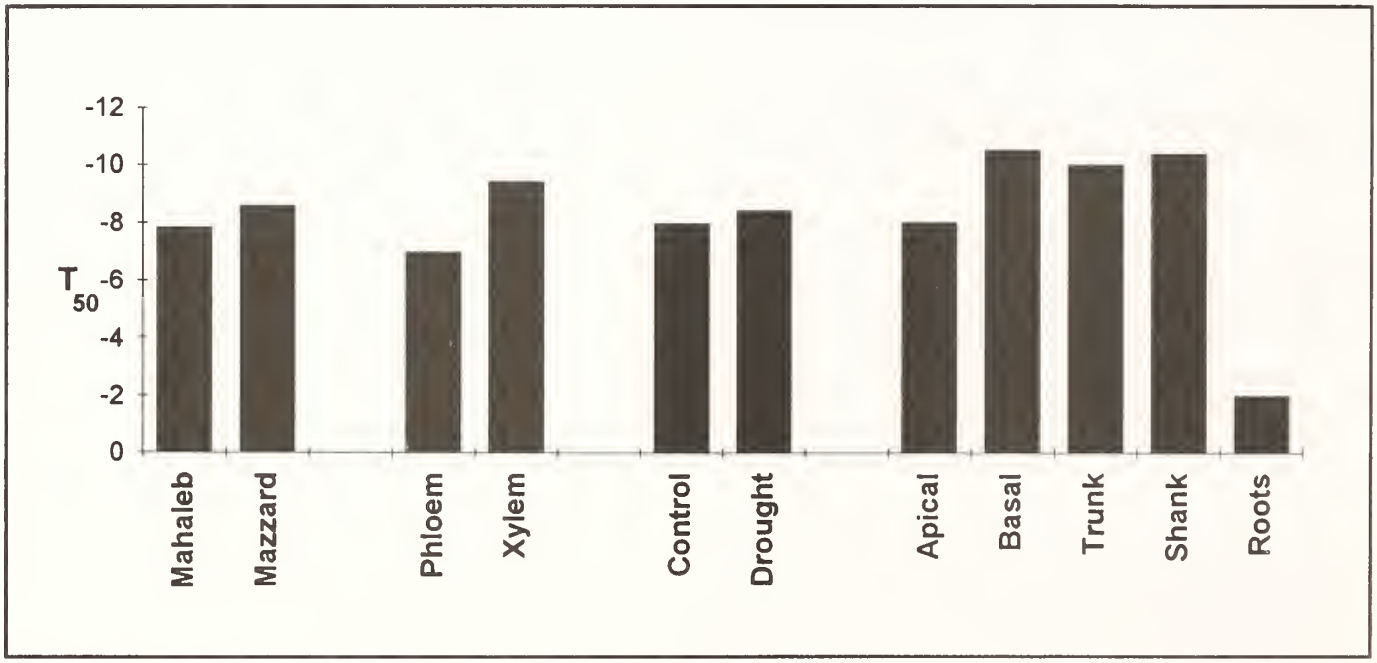


Figure 2. T_{50} Main effect means for tissues collected on October 17, 1991. Tissue and position were significant at the P=.0001 level. Rootstock was significant at the P=.03 level. Drought was not significant.

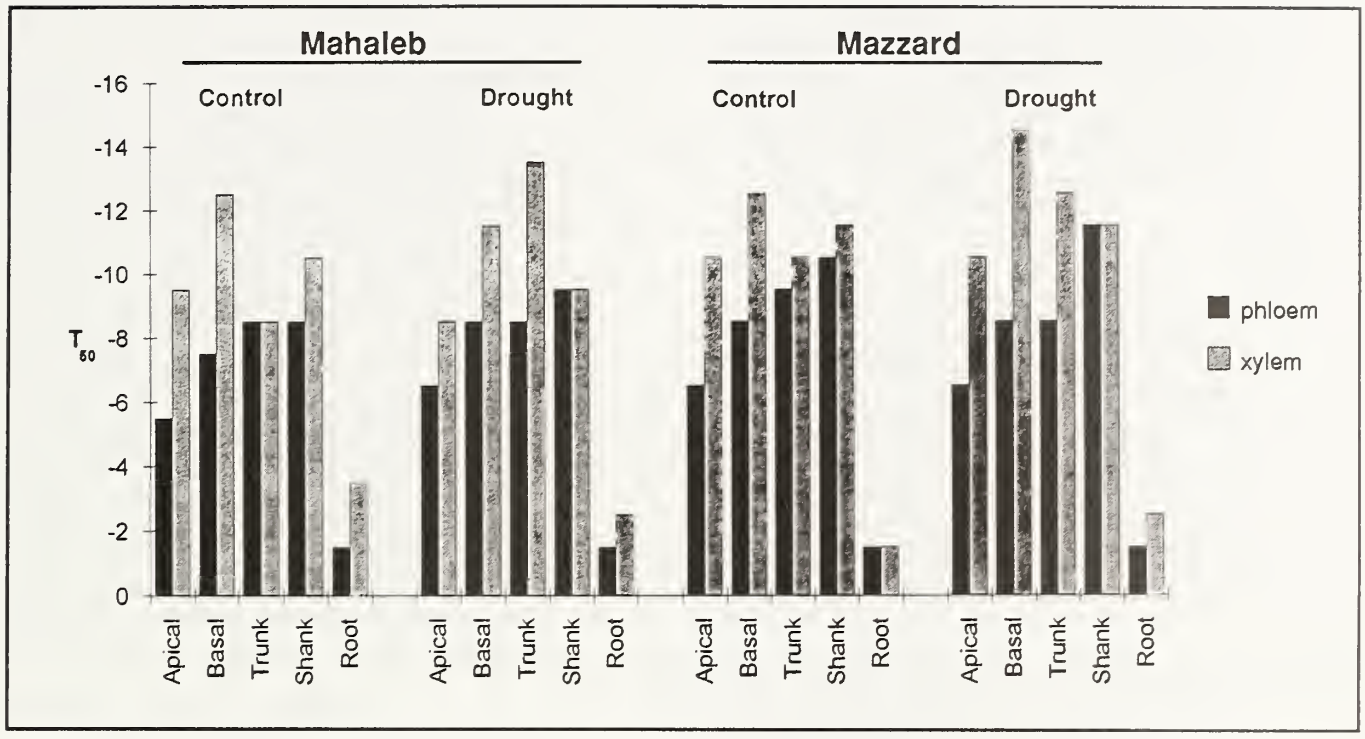


Figure 3. T_{50} cold hardiness values for tissues collected on October 17, 1991.

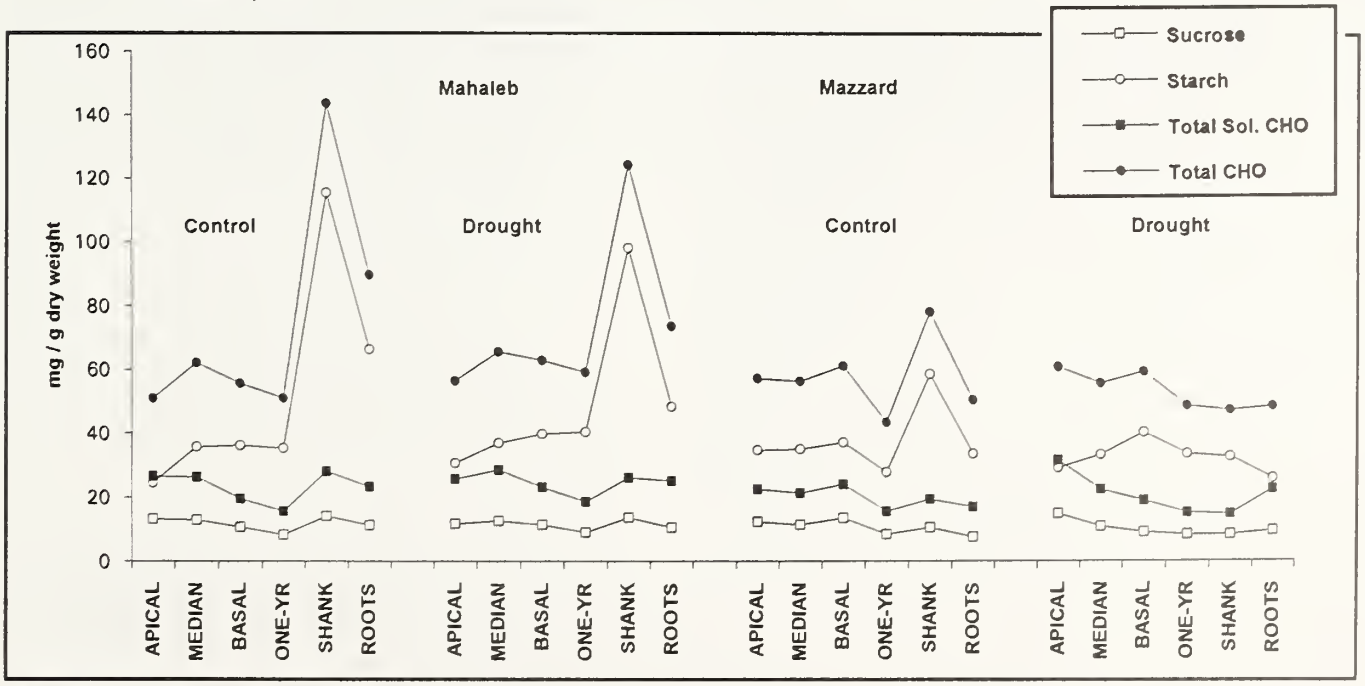


Figure 4. The total and major nonstructural carbohydrate concentrations in tissues collected on October 17, 1991. Sucrose is the major soluble carbohydrate.

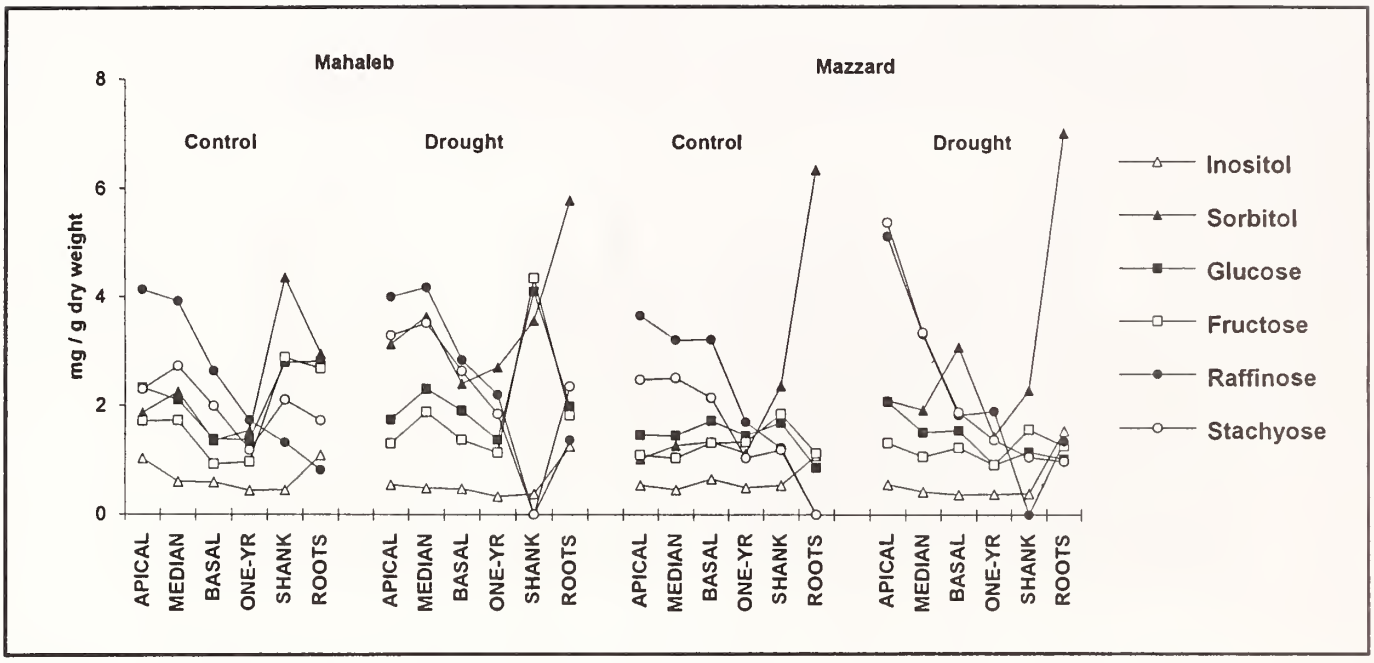


Figure 5. The individual minor soluble carbohydrates concentrations in tissues collected on October 17, 1991.

INFLUENCE OF SCION CULTIVAR ON INCIDENCE OF PEACH TREE SHORT LIFE

T.G. Beckman[1], W.R. Okie[1] and A.P. Nyczepir[2]

INTRODUCTION

Peach [*Prunus persica* (L.) Batsch] trees are predisposed to peach tree short life (PTSL) by the ring nematode [*Criconemella xenoplax* (Raski) Luc & Raski (*Mesocriconema xenoplax*)] (Nyczepir, 1990; Nyczepir et al., 1983; Ritchie and Clayton, 1981). However, the actual cause of death is suspected to be either cold injury or bacterial canker (*Pseudomonas syringae* pv *syringae* van Hall) of the scion. In contrast, the rootstock usually survives and may produce suckers. Rootstocks have been identified which either enhance or reduce incidence of PTSL (Yadava and Doud, 1989; Dozier et al., 1984; Brittain and Miller, 1978) but very little is known about the effect of the scion variety on susceptibility of a scion/rootstock combination to PTSL. The purpose of this study was to determine the influence of the scion variety on the incidence of PTSL on Nemaguard rootstock.

MATERIALS AND METHODS

Fifty different scion/rootstock combinations were prepared by a commercial nursery in the summer of 1986 (June-budded). Scion treatments included 49 different scion cultivars budded onto open-pollinated Nemaguard seedlings, plus virus free 'Redhaven' budded onto open-pollinated Lovell seedlings (seed from Clemson University virus-free program). Scion varieties included standard cultivars and rootstocks, experimental rootstocks and Plant Introductions (Table 1). Trees were planted in the spring of 1987 in central Georgia at the Southeastern Fruit and Tree Nut Research Laboratory with a spacing of 1.2 x 6.1 m on a site with a previous history of PTSL. Trees were managed according to Georgia Extension Service recommendations (Myers, 1989). Trees were fertilized each spring with a single broadcast application of ammonium nitrate (56 kg actual N/ha). No supplemental irrigation was applied. Trees were initially trained by hand to an open-center with main plot pruning treatments commencing in the fall of 1988.

Pruning treatments were applied with a tractor-mounted sickle bar mower which removed one-third to one-half of the previous season's growth from the top and sides of the trees (tree size following winter 1991-92 pruning: ca. 2 m height, 2.5 m width across rows and 1.5 m width within row with some branch interweaving). Starting in the fall of 1989 trunk diameters were measured 30 cm above the soil line each year. Dead and dying trees were inspected each spring (typically early May) to determine the cause of death, i.e. PTSL, oak root rot [*Armillaria tabescens* (Scop.) Dennis, Orton and Hora] or unknown. Trees that died from causes other than PTSL were excluded from subsequent analyses (resulting in the loss of 68 trees through spring of 1992).

Trees were planted in a split-plot design with 10 blocks. The main plot treatment was pruning time, i.e. fall (typically December) vs. spring (typically March). The sub-plot treatment was the 50 different scion/rootstock combinations (single tree plots). Analysis of Variance (ANOVA) was performed with PROC ANOVA (SAS, 1987) although we recognize the limitations of this analysis on binomial survival data (0 = dead, 1=alive). For ANOVA, sucker count data was transformed as square root of number of suckers plus 0.5 as suggested by Gomez and Gomez (1984) for count data of this type. Mean separation of percent survival was performed with a cluster analysis technique reported by Scott and Knott (1974) and illustrated by Gates and Bilbro (1978). Linear correlations were performed with PROC CORR (SAS, 1987).

RESULTS AND DISCUSSION

Through spring of 1992 tree mortality was significantly greater in the fall-pruned

[1]Research Horticulturist, USDA-ARS, Southeastern Fruit and Tree Nut Research Laboratory, P.O. Box 87, Byron, GA 31008

[2]Research Nematologist, USDA-ARS, Southeastern Fruit and Tree Nut Research Laboratory, P.O. Box 87, Byron, GA 31008

treatment (Table 2) which is consistent with previous reports (Brittain and Miller, 1978; Nyczepir, 1990). There was no interaction between pruning treatment and scion variety. Scion variety exerted a marked influence on tree survival (Table 1). The range in influence is comparable to that exhibited by Lovell and Nemaguard as rootstocks under 'Redhaven'. Lovell's consistently better performance than Nemaguard as a rootstock on PTSL sites has led to its being strongly recommended for use under such circumstances (Brittain and Miller, 1978). Very few previous studies have reported significant differences in susceptibility to PTSL between scion varieties grafted to the same rootstock. Dozier et al. (1984) noted that during a S-97 regional rootstock trial, trees grafted with 'Loring' survived better than those grafted with 'Redhaven' at all test sites. However, differences were significant at only 2 of the 5 locations. To date, 'Loring' has provided a nonsignificant numerical advantage in survival over 'Redhaven' as a scion variety in our study.

Correlations between trunk cross sectional area (TCSA) or relative growth rate (RGR) and survival were generally nonsignificant and variable (data not shown). Weak positive correlations between annual sucker production and survival were also generally nonsignificant (data not shown). However, a better correlation was observed between average full bloom date and survival, $r = -0.31$ ($P < 0.05$). Trees which bloomed earlier tended to live longer. The opposite relationship was evident between mean fall defoliation date and survival, $r = 0.33$ ($P < 0.05$). In this case trees which defoliated later tended to live longer. As might be expected a good correlation was observed between mean length of growing season in 1990 and 1991 (days from full bloom to fall defoliation) and survival, $r = 0.49$ and 0.47, respectively ($P < 0.001$). Trees which exhibited the longest growing season also tended to exhibit the best survival.

If cold injury were the principle cause of death in this experiment one might reasonably expect trees which bloomed earlier in the spring to be more susceptible in contrast to the results observed. Alternatively, length of growing season might be related to carbohydrate accumulation which could be expected to enhance cold hardiness of a given scion variety. Additional data on carbohydrate status (as influenced by either crop load or length of growing season) would be useful in determining the importance of this factor.

Yadava and Doud (1989) noted a similar relationship between fall defoliation and incidence of PTSL. In an experiment with open-pollinated seedling rootstocks on a PTSL site, Weaver, et al. (1979) reported that NA8, 152Al2 and Lovell exhibited better resistance than did Siberian C following inoculation with the causal agent of bacterial canker. These results are consistent with those reported here using these rootstock varieties as scions on a uniform rootstock.

The results of this study demonstrate that the scion influence on PTSL incidence may be comparable to that exerted by rootstock. This finding has important implications. First, rootstock testing with ungrafted materials may incorrectly infer a rootstock influence on survival that may be primarily the result of the scion tissue. Hence, ungrafted tests must be followed up with a grafted trial, preferably with a scion variety that enhances susceptibility to PTSL (e.g. 'Redhaven'), before any firm conclusions on the rootstock influence of a candidate line can be made. Secondly, if the effect of a given scion variety proves uniform across a range of rootstocks, then growers may be able to tailor their choice of scion varieties to their planting sites, i.e. those sites with a proven history of PTSL should be planted not only with the most resistant rootstocks but also with the most resistant scion varieties.

The results of this trial are inconclusive regarding the relative importance of the recognized principal killing agents in PTSL, e.g. cold injury and bacterial canker. The apparently superior survival of early blooming varieties seems to discount cold injury as a primary agent. However, this may because a long growing

season or low cropping (due to frost injury) may compensate. Moreover, cold hardiness and early bloom are not necessarily mutually exclusive, nor are cold hardiness and PTSL-related cold injury in the spring. Correlations between late defoliation and survival are in agreement with previous studies and are consistent with suggested roles for bacterial canker in PTSL either through the establishment of infection courts or genetic resistance.

LITERATURE CITED

Brittain, J.A. and R.W. Miller, Jr. (eds.). 1978. Managing peach tree short life in the Southeast. Clemson Univ. Coop. Agr. Ext. Serv. Circ. 585.

Dozier, W.A., J.W. Knowles, C.C. Carlton, R.C. Rom, E.H. Arrington, E.J. Wehunt, U.L. Yadava, S.L. Doud, D.F. Ritchie, C.N. Clayton, E.I. Zehr, C.E. Gambrell, J.A. Britton and D.W. Lockwood. 1984. Survival, growth, and yield of peach trees as affected by rootstock. HortScience 19:26-30.

Gates, C.E. and J.D. Bilbro. 1978. Illustrations of a cluster analysis method for mean separation. Agron. J. 70:462-465.

Gomez, K.A. and A.A. Gomez. 1984. Statistical procedures for agricultural research. 680 Pp. Wiley, New York.

Myers, S.C. (ed.) 1989. Peach Production Handbook. GA Ext. Hdbk. No. 1. Coop. Ext. Serv., The Univ. of GA, Athens, GA. 221 Pp.

Nyczepir, A.P. 1990. Influence of *Criconemella xenoplax* and pruning time on short life of peach trees. J. Nematol. 22:97-100.

Nyczepir, A.P., E.I. Zehr, S.A. Lewis and D.C. Harshman. 1983. Short life of peach trees induced by *Criconemella xenoplax*. Plant Dis. 67:507-508.

Ritchie, D.F. and C.N. Clayton. 1981. Peach tree short life: A complex of interacting factors. Plant Dis. 65:462-469.

SAS. 1987. SAS/STAT guide for personal computers. Version 6. SAS Institute, Cary, NC.

Scott, A.J. and M. Knott. 1974. A cluster analysis method for grouping means in the analysis of variance. Biometrics 30:507-512.

Weaver, D.J., S.L. Doud and E.J. Wehunt. 1979. Evaluation of peach seedling rootstocks for susceptibility to bacterial canker, caused by *Pseudomonas syringae*. Plant Dis. Rep. 63:364-367.

Yadava, U.L. and S.L. Doud. 1989. Rootstock and scion influence growth, productivity, survival, and short life-related performance of peach trees. J. Amer. Soc. Hort. Sci. 114:875-880.

Table 1. Scion influence on survival of peach trees on a PTSL site (through spring, 1992 at Byron, GA).

Scion[z]	Survival (%)
Agua 6-4	85.0 a[y]
Flordaguard	85.0 a
Salcaja	73.7 a
TN#4 (J67-34)	70.6 a
NJ 6821180	70.6 a
NJ 5110417	70.6 a
Transvaal Yellow	70.0 a
Redglobe	61.1 b
Fireprince	60.0 b
Reliance	58.8 b
Redhaven/Lovell	57.9 b
Nemaguard	57.9 b
GA102	55.6 b
J68-271	55.6 b
Lovell VF	55.6 b
Bailey	50.0 b
Soleil d'Octobre	50.0 b
Springcrest	50.0 b

(Table 1 Continued)

14DR51	50.0 b
PI91459	50.0 b
Elberta	47.4 b
Ku Chang Hung #14	47.4 b
TN#2 (Row 2)	45.0 b
P31-29	44.4 b
Flavortop	43.8 b
NA8	42.1 b
Cresthaven	41.2 b
Sunland	38.9 c
SCRS1	31.6 c
NJ 6822270	30.0 c
PI133987	30.0 c
Loring	27.8 c
152AI2LRL2	26.7 c
Junegold	26.3 c
J68-69	26.3 c
NJ 555052	26.3 c
SL2891 (520-9)	26.3 c
Halford	26.3 c
South Hero	26.3 c
Redhaven	25.0 c
Dixired	22.2 c
Durbin	20.0 c
Shiron Donak	15.8 c
Stark RL	15.8 c
Mayflower	15.8 c
Krasvynos	15.0 c
PI102705	10.5 c
Siberian C	10.5 c
Amarillo Tardio	6.3 c
Pi Tao	5.6 c

[z]Unless otherwise indicated all scions were budded to Nemaguard op.
[y]Significance of divisions: AB, $P < 0.05$; BC, $P < 0.005$.

Table 2. Effect of pruning time on survival of peach trees on a PTSL site (through spring, 1992 at Byron, GA).

Pruning Treatment	Survival (%)
Fall	35.8*
Winter	46.4

*Significant at $P = 0.05$ (F test).

UPDATE ON PEACH TREE FUNGAL GUMMOSIS IN THE SOUTHEAST

P.L. Pusey[1] and W.R. Okie[2]

ABSTRACT

Previous work indicated that a control program for peach tree fungal gummosis caused by *Botryosphaeria dothidea* should include proper sanitation practices and irrigation to reduce water stress. Recently, progress was made in the development of other control strategies that could greatly improve the overall management of this disease. An effective method of screening for resistance in young peach trees to gummosis was developed. Initial results were obtained within 9 months, which is about 2 years sooner than the time generally required for symptom development under normal field conditions. Also, chemical control was achieved for the first time. This was initially attempted by making one dormant application with materials including $CaCO_3$ or latex paint combined with $CuSO_4$. These treatments had little or no effect. However, it was found that captafol and captan (both at 2.4 g a.i. per liter) applied at 2-week intervals during the period of infection effectively controlled peach gummosis. The economic feasibility of such treatments is discussed. Evidence presented indicates that fungicide protection of the trunk and major branches of peach trees may be necessary only during the first 3 years after planting.

INTRODUCTION

Peach tree fungal gummosis was first noticed in Georgia in the 1960's (Weaver, 1974) and has since appeared in peach-production areas in much of the southeastern United States (Pusey et al., 1986; Reilly and Okie, 1982). Symptoms of this disease have also been reported in Japan (Abiko and Kitajima, 1970), China (Chen, 1985), and Australia (J. Slack, pers. comm.). The disease is characterized by multiple infection sites that are associated with lenticels of the bark (Pusey et al., 1986; Weaver, 1974; Weaver, 1979). These localized infections are manifested as blisters on 1- to 3-year-old bark and sunken necrotic lesions, some of which exude gum, on bark 2 years of age and older. Lesions may coalesce, forming large areas of necrosis which can result in the death of branches or the entire tree. The disease is caused by a physiologic race of the fungus, *Botryosphaeria dothidea* (Moug. ex Fr.) Ces. & de Not. (Pusey et al., 1986). Primary infections in peach orchards may be due to airborne sexual spores (ascospores) which are at peak levels in March and April (Pusey, 1989a). However, spread of the disease within the orchard is thought to occur mainly by the dispersal of asexual spores (conidia) carried in splashing and wind-driven rain. On individual trees, spores are often carried downward in rainwater from higher locations where the fungus has invaded pruning wounds or become established as a saprophyte. Waterborne spores are potentially available during most of the year and are generally detected throughout the growing season whenever it rains (Pusey, 1989a). Inoculations made periodically in two different years indicated that the peak period when uninjured bark can be infected by waterborne spores is from late April through July or early August (Pusey and Bertrand, 1993).

Efforts are now being made to develop a control strategy for peach tree fungal gummosis. An effective management program will necessarily include good sanitation practices, as dead wood can be a source of spore inoculum in the orchard (Pusey, 1989a). Ideally, dead prunings should be removed from the orchard and burned. There is some evidence, based on work with *B. obtusa* on apple (Starkey and Hendrix, 1980), that a flail mower is much more effective than a conventional rotary mower in reducing the amount of dead wood on which the pathogen can successfully colonize and sporulate. It will also be important to maintain trees in a stress-free condition, as various types of environmental or physiological stress have been

---

[1]Research Plant Pathologist, USDA-ARS, Southeastern Fruit and Tree Nut Research Laboratory, P.O. Box 87, Byron, GA 31008

[2]Research Horticulturist, USDA-ARS, Southeastern Fruit and Tree Nut Research Laboratory, P.O. Box 87, Byron, GA 31008

known to predispose various tree species to infection by *B. dothidea* (Schoeneweiss, 1981). It was demonstrated in greenhouse experiments that water stress, particularly when imposed during August through October, dramatically increased disease severity (Pusey, 1989b). This is of special significance because growers, even those with irrigation systems, do not irrigate after harvest, which may occur as early as May or as late as August. In addition, periods of drought are common in the Southeast in September and October. Recently, progress has been made in two areas of attack that could become part of an overall strategy of controlling peach tree fungal gummosis. In the present paper, we have described in some detail this work.

The first area of research deals with natural resistance in peach (see I. below). It has been recognized for a number of years that some variation in resistance to peach tree fungal gummosis exists among peach cultivars. Previous efforts to screen trees under natural field conditions have been inadequate because it often takes 3 years or longer after planting before evaluations can be made (Daniell and Chandler, 1982; Okie and Reilly, 1983). One technique used involved the artificial inoculation of wounds made on twigs (Reilly and Okie, 1982). This method produced results within one season; however, the results may not reflect differences in the susceptibility of peach bark to invasion through natural openings such as lenticels. This is of critical importance based on our present understanding of the disease. Therefore, a system was devised to accelerate disease development on young, uninjured peach trees in close-planted field plots.

Progress has also been made in utilizing chemicals for control of peach gummosis (see II. below). Initial efforts focused on dormant treatments involving the application of calcium carbonate and copper compounds, a recommended practice in Japan for control of what appears, from all indication, to be the same disease of peach. More recently, an orchard study was initiated to: (a) demonstrate that peach tree fungal gummosis can be controlled with fungicides applied at regular intervals during the infection period and (b) to study the economic impact of peach tree fungal gummosis based on comparisons between diseased trees and those that have been protected with fungicides. The second objective would be made possible by the first. Questions regarding the economic importance of peach tree fungal gummosis have gone unanswered because the disease generally occurs uniformly throughout whole orchards, making comparisons at the same site difficult or impossible.

I. DISEASE RESISTANCE

Materials and Methods. A trellis-like structure was built consisting of cross-shaped wooden supports, each with 1.2-m-long horizontal piece attached 2 m above ground, and spaced 10 m apart. Three wires were stretched the length of the row and supported on the horizontal piece, one at the center and one at each of the two ends. On 7 January 1991, 17 different peach lines that had been custom budded on Lovell rootstock by a nursery (Table 1) were planted at a 0.6-m spacing below the wires. At about the same time that trees were planted, freshly-cut pruning wood was collected from a nearby peach orchard. The prunings were sprayed with a spore suspension of *B. dothidea* (10^5 spores per ml) to insure colonization by the fungus, piled in a wooded area for 3 weeks, and then laid perpendicular across the top of the support wires at a spacing of 1.2 -1.8 m. To secure the prunings, additional prunings were laid end to end on top and attached to each of the outside wires. A perforated hose which emitted water as a mist was attached at top center on the support system. The mist came on each hour for 10 min from 7 a.m. to 7 p.m. during the period from April through August. The purpose of the mist was to disperse spores produced on the dead pruning wood to the trees below and create conditions favorable for infection.

Results and Discussion. Beginning in August 1991, blisters were observed on the bark of a large portion of the test trees. Little or no gumming was observed in 1991. When the trunk and

branches of trees were evaluated on 23 September 1991 for blister formation using a 0-5 rating scale (0 = no blisters and 5 = blisters present on most of bark surface), mean ratings ranged from 0.13 for PI65821 to 2.8 for Summergold (Fig. 1A). By the following Spring, many trees exhibited profuse gumming and trees of several different lines had died as a result of infection by *B. dothidea*. When trees were evaluated 14 May 1992 using a 0-5 rating scale (0 = no visible gum, 1 = few gum deposits, 2 = few gum deposits on trunk and each major branch, 3 = heavy gumming on trunk and branches, 4 = some dieback, and 5 = tree dead), mean ratings ranged from 0 for NRL-1 to 4.9 for GF557 (Fig. 1B). Of all trees tested, 13.8 % had died. By 13 October 1992, overall mortality had increased to 28.8 %; tree lines with the least amount of gummosis were NRL-1 and PI65821 with mean ratings of 0.6 and 0.7, respectively.

The technique proved to be an effective screening method. Currently, efforts are being made to test young seedlings. Success with seedling or clonal material would further shorten the time required for screening peach germplasm. Plans have also been made to study the response of susceptible and resistant tree lines using histochemical methods, in an effort to improve the early selection of resistant types.

II. CHEMICAL CONTROL

Materials and Methods. The use of dormant treatments to control peach tree fungal gummosis was first attempted in a test beginning in 1988 using newly planted trees of the cultivar Summergold at two farms in central Georgia. At both locations, the plantings were surrounded by adjacent blocks of mature peach trees with severe symptoms of peach tree fungal gummosis. (One of the two test sites had to be abandoned later due to extensive tree death apparently caused by a pesticide previously applied to the soil.) Prior to bud break (or soon after) in 1988, 1989 and 1990, white latex paint or products consisting of calcium carbonate and a polymer (Pichicoat, produced by Aokura Sekai, Japan; and Whiton Powder, produced by Shiraishi Calcium Kaisha, Ltd., Japan) were applied with a hand sprayer to the trunks of trees. These materials were applied alone or in combination with copper sulfate. The calcium-carbonate products were prepared by adding 1 Kg of product to 3 L of water as recommended by the manufacturers. In 1988, copper sulfate was applied at 10 g/L (in the prepared product); this was increased to 20 g/L in 1989 and 1990. As an additional treatment, Bordeaux mixture (1:1; copper sulfate and lime) was applied at 20 g/L in 1988 and 40 g/L in the years following. Each treatment was performed with 15 single-tree replicates in a completely randomized design.

A similar test involving dormant treatments was initiated in March 1989, using newly planted peach trees of the cultivar Sunbrite at two different locations near Fort Valley, GA. The following treatments were applied to the trunk prior to bud break (or soon after) in 1989, 1990 and 1991: (a) Untreated control; (b) Whiton Powder; (c) latex paint; (d) Tribasic Copper Sulfate (Tennessee Chemical Co.), 20 g/L; (e) Tenn-Cop 5E (Tennessee Chemical Co), 100 ml/L; (f) Whiton-Do (Whiton Powder preformulated by manufacturer with copper hydroxide); (g) Whiton Powder + Tribasic Copper Sulfate, 20 g/L; (h) Latex paint + Tribasic Copper Sulfate, 20 g/L; (i) Tenn-Cop 5E, 80 ml/L, plus Tribasic Copper Sulfate, 16 g/L; (j) Captan, 2.4 g a.i. per liter; and (k) Whiton Powder + Captan, 2.4 g a.i. per liter. Whiton Powder and Whiton-Do were prepared as above. Each treatment was performed with 15 trees in a completely randomized design.

As another approach, fungicides were applied repeatedly to peach trees during the period of infection by *B. dothidea*. A test orchard was established at Byron, GA, not only to demonstrate chemical control, but also to study the economic impact of peach tree fungal gummosis. To insure maximum inoculum levels, a site was prepared inside a 13-yr-old block of Redglobe peach trees showing severe peach tree fungal gummosis symptoms. Trees were removed from the center of the old block and those to the outside were left in place to form a two-tree border completely surrounding the planting site. Soil preparation

included fumigation with methyl bromide. Trees of the highly susceptible cultivar, Summergold, were planted in February 1990 at a spacing of 6.1 X 6.1 m. For each treatment, there were 10 replicate plots of three trees in a randomized complete block design. Captafol (Difolatan 80WP; 2.4 g a.i. per liter), captan (Captan 50WP; 2.4 g a.i. per liter) or Tenn-Cop (6.3 ml/L) was applied with a hand sprayer at 2-week intervals from mid-April to early August (8-9 sprays total) in 1990, 1991 and 1992. (Captafol, which is no longer sold in the U.S., was used as a research tool and not as a potential fungicide for use in commercial peach orchards.) Bark on the trunk and branches of trees was covered to the point of run-off. As a fourth treatment, Whiton Powder combined with Tribasic Copper Sulfate at 8.7 g/L was applied yearly prior to bud break to the trunk and branches. In addition to an untreated control group, another set of trees was subjected to higher inoculum levels of *B. dothidea* by placing in the scaffold of each tree four dead prunings bearing the fungus. This was done each year using prunings recently cut from mature trees and spray-inoculated with *B. dothidea*.

Results. For the dormant-treatment test initiated in 1988, the trunks of trees were evaluated for disease in November 1990 by counting gum deposits and again in March 1992 using a 0-5 rating scale based on the number of gumming sites per 100 cm^2 of bark area (0 = no gum, 1 = 0-1 sites/100 cm^2, 2 = 1-5 sites/100 cm^2, 3 = 5-20 sites/100 cm^2, 4 = 20-60 sites/100 cm^2, 5 = over 60 sites/100 cm^2). In both evaluations, none of the treatments resulted in mean values significantly lower than that of the untreated control (Fig. 2).

For the dormant-treatment test initiated in 1989, trunks were rated in March 1992 using the above scale based on the density at which gumming sites appeared. In one orchard, none of the treatments resulted in mean ratings that were lower than the control (Figure 3A). In the other orchard, some treatments resulted in statistically lower ratings than the control, but still allowed for a substantial amount of disease development (Figure 3B).

In the test orchard where fungicides were applied repeatedly during the infection period, high inoculum levels and high rainfall resulted in early symptom development. The trunks and branches of trees were rated for gum exudation in October of 1991 and 1992 using the above scale based on density. Captafol and captan were shown to effectively control peach tree fungal gummosis and the other treatents had no effect (Fig. 4 and 5). Results with these two fungicides were not different in 1991; but in 1992, the treatment with captafol was shown to be superior to that with captan.

Discussion. Materials applied to peach trees prior to or soon after bud break formed physical and chemical barriers that were probably effective initially in protecting trees from *B. dothidea*. However, these barriers appeared to crack and deteriorate during the season as trees grew and expanded. Thus, openings were created for the pathogen to enter. This approach does not show promise as a method of controlling peach tree fungal gummosis.

On the other hand, captafol and captan applied repeatedly to peach trees during the infection period provided excellent control of gummosis. Although the best results were achieved with captafol, a fungicide no longer available to growers in the U.S., the efficacy of captan approached that of captafol.

It is far too early to draw conclusions from the latter test regarding the economic importance of peach tree fungal gummosis based on its effects on growth, productivity, or tree longevity. Nonetheless, there is already some indication that gummosis affected growth, since trees treated with captafol had a slightly larger trunk diameter ($P \leq 0.05$) than other trees after 3 years. Trees treated with captafol also defoliated later in the fall. Yield data was collected initially in 1992, but no differences were detected in total fruit weight. However, it

was found that disease severity was positively correlated with the earliness of fruit maturation ($P = 0.001$).

The economic feasibility of controlling peach tree fungal gummosis with multiple applications of fungicides is questionable. Possibly, the period or frequency of sprays could be reduced. Protection during the months of June and July would be of particular importance. Also, there is now evidence that fungicide protection on the trunk and major branches may not be necessary beyond the third year after planting. A previous orchard study (Pusey and Bertrand, 1993) conducted to determine when trees are infected by natural inoculum recently led to an interesting observation. Plastic covers and silicone caulking were used to protect the trunks of trees from spore inoculum following planting, except during various periods when trees were exposed. Five years after trees were planted, bark that had been covered only during the first 2 years was, in many cases, free of disease, whereas bark above this area was severely diseased (Fig. 6). The implication is that fungicide protection may not be necessary beyond the second year for bark on the trunk, and beyond the third year for bark on the lower scaffold, which is one year younger. A possible relationship between bark age and susceptibility was also indicated in work by Weaver (1979), who inoculated bark varying in age from 1- to 3-years-old. If it is found that fungicide sprays are needed only in the early years of the orchard, the practicality of chemical control will be greatly improved.

LITERATURE CITED

Abiko, K. and H. Kitajima. 1970. Blister canker, a new disease of peach tree. Ann. Phytopathology Soc. Japan 36:260-265.

Chen, X.Z. 1985. Studies on the gummosis of peach (*Prunus persica*) caused by *Botryosphaeria dothidea*. Acta Phytopathology Sinica 15:53-57.

Daniell, J.W. and W.A. Chandler. 1982. Field resistance of peach cultivars to gummosis disease. HortScience 17:375-376.

Okie, W.R. and C.C. Reilly. 1983. Reaction of peach and nectarine cultivars and selections to infection by *Botryosphaeria dothidea*. J. Amer. Soc. Hort. Sci. 108:176-179.

Pusey, P.L. 1989a. Availability and dispersal of ascospores and conidia of *Botryosphaeria* in peach orchards. Phytopathology 79:635-639.

Pusey, P.L. 1989b. Influence of water stress on susceptibility of nonwounded peach bark to *Botryosphaeria dothidea*. Plant Dis. 73:1000-1003.

Pusey, P.L. and P.F. Bertrand. 1993. Seasonal infection of nonwounded peach bark by *Botryosphaeria dothidea*. Phytopathology. (In press)

Pusey, P.L., C.C. Reilly and W.R. Okie. 1986. Symptomatic responses of peach trees to various isolates of *Botryosphaeria dothidea*. Plant Dis. 70:568-572.

Reilly, C.C. and W.R. Okie. 1982. Distribution in the southeastern United States of peach tree fungal gummosis by *Botryosphaeria dothidea*. Plant Dis. 66:158-161.

Schoeneweiss, D.F. 1981. The role of environmental stress in diseases of woody plants. Plant Dis. 65:308-314.

Starkey, T.E. and F.F. Hendrix. 1980. Reduction of substrate colonization by *Botryosphaeria obtusa*. Plant Dis. 64:292-294.

Weaver, D.J. 1974. A gummosis disease of peach trees caused by *Botryosphaeria dothidea*. Phytopathology 64:1429-1432.

Weaver, D.J. 1979. Role of conidia of *Botryosphaeria dothidea* in the natural spread of peach tree gummosis. Phytopathology 69:330-334.

Table 1. Peach tree lines used in testing a new procedure of screening for resistance in peach to gummosis caused by *Botryosphaeria dothidea*.

Tree line designation	Origin
PI134151	Transvaal Yellow, canning peach from South Africa
PI151158	Royal George from Argentina
PI36126	Bolivian Cling from Bolivia
PI43289	Eagle Beak from south China
PI65821	Shau Thai Tao from China
GF557	Peach X almond rootstock from France
BY86P200	F_1 seedling of Harbrite X Eagle Beak
BY86P201	F_1 seedling of Harbrite X Eagle Beak
BY86P202	F_1 seedling of Harbrite X Eagle Beak
Nema-2	Nemaguard seedling
Nema-3	Nemaguard seedling
Nema-4	Nemaguard seedling
NRL-1	NRL-4 seedling (Nemaguard X Rutger's Redleaf)
TN-1	Tennessee Natural seedling
Eagle Beak	Seedling of PI43289
Harbrite	Commercial peach from Ontario
Summergold	Commercial peach developed at Byron

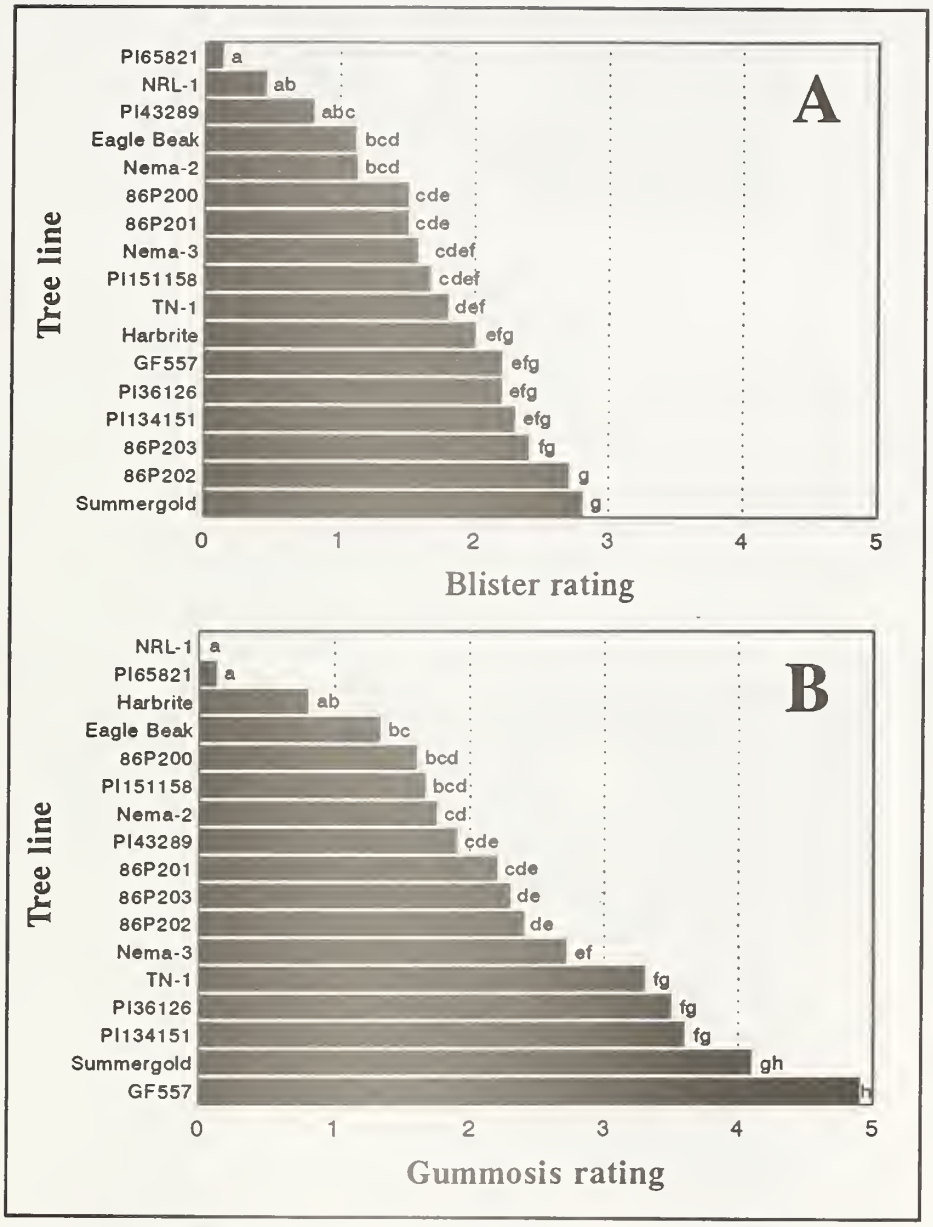


Figure 1. Trellis method of screening for resistance in peach tree lines to fungal gummosis. (A) Results of 0–5 rating based on blister formation in September 1992, less than 9 months after planting. (B) Results of 0–5 rating based on fungal gummosis and tree death 16 months after planting. Bars represent mean ratings; those with the same letters are not different according to Waller-Duncan K-ratio T test (K-ratio = 100).

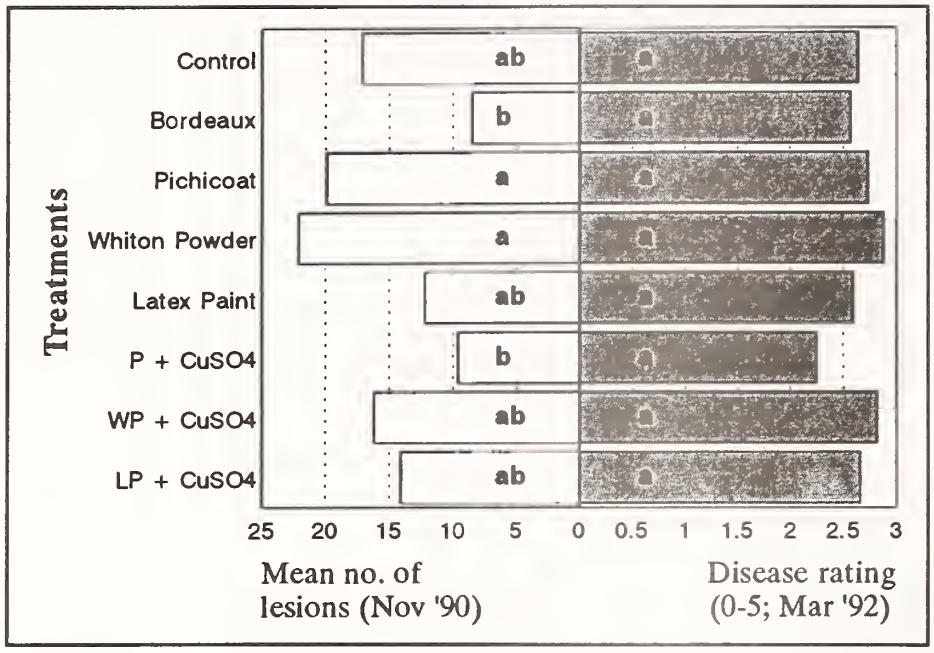


Figure 2. Results of treatments applied to peach trees near bud break each year beginning after planting in 1988 to control peach tree fungal gummosis in commercial orchard. White latex paint (LP) or $CaCO_3$ products from Japan, Pichicoat (P) and Whiton Powder (WP), were applied to tree trunks alone or in combination with $CuSO_4$ (10–20 g/L). Bars represent mean values; those with the same letters are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

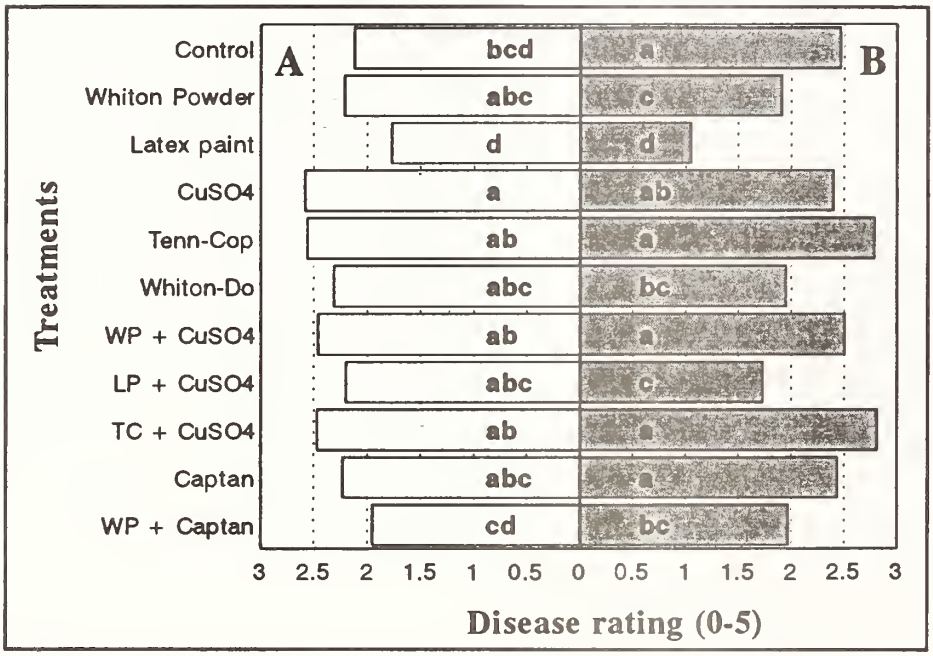


Figure 3. Results of treatments applied to peach trees near bud break beginning after planting in 1989 to control fungal gummosis in commercial orchards (A and B). Treatments or combinations included latex paint (LP), Tribasic $CuSO_4$ (16–20 g/L), Tenn-Cop 5E (TC; 80–100 ml/L), captan (2.4 g a.i. per liter), and $CaCO_3$ products from Japan, Whiton Powder (WP) and Whiton-Do, the latter being formulated with $Cu(OH)_2$. Bars represent mean disease ratings; those with the same letters are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

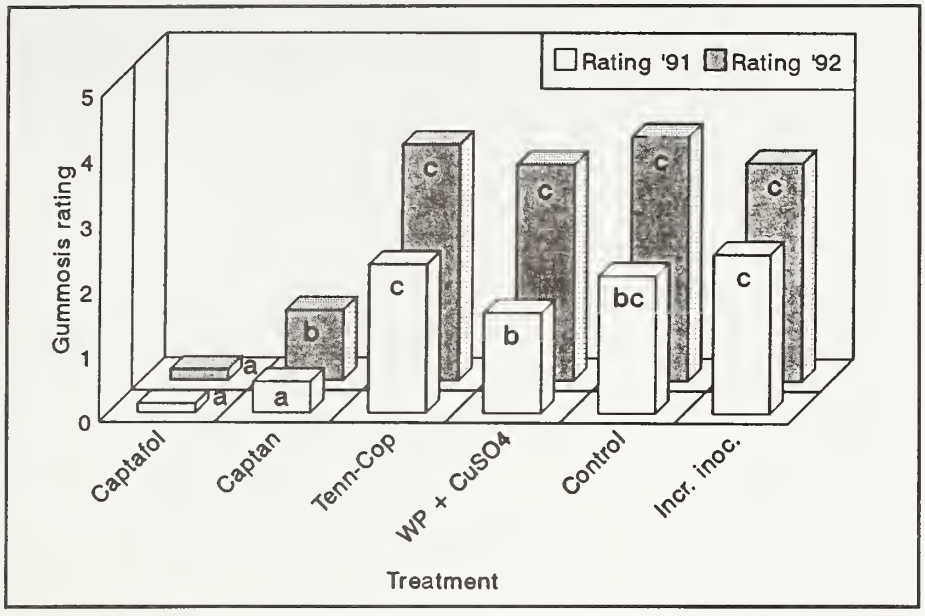


Figure 4. Results of fungicides applied at 2-week intervals from mid-April to early August beginning after planting in 1990 to control peach tree fungal gummosis. In addition to repeated sprays with captafol and captan (both at 2.4 g a.i. per liter) and Tenn-Cop 5E (6.3 ml/L), one treatment group was treated once near bud break with Whiton Powder plus $CuSO_4$ (87 g/L). Another set of trees was subjected to higher inoculum levels (Incr. inoc.) by placing in the scaffold dead wood bearing the pathogen. Each bar represents mean disease rating (0–5) in 1991 or 1992; within one year, those with the same letters are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

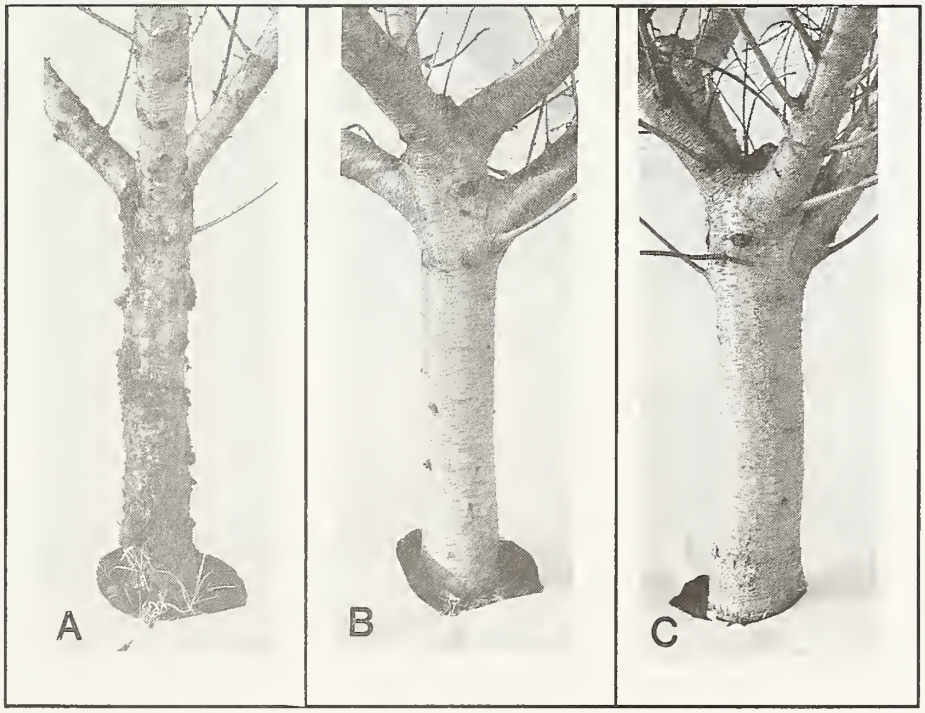


Figure 5. Trees treated with fungicides at 2-week intervals from mid-April to early August beginning after planting in 1990 to control peach tree fungal gummosis. (A) Control tree that received no fungicide, (B) tree treated with captan, and (C) treated with captafol. Both fungicides were applied at 2.4 g a.i. per liter. Photographs were taken in December 1992.

Figure 6. Five-year-old peach tree exhibiting disease-free bark (at base) where trunk had been physically protected from inoculum of *Botryosphaeria dothidea* during the first 2 years after planting; by contrast, the area above shows severe disease symptoms. Protection was accomplished with a plastic cover and silicone caulking as part of previous epidemiological study (Pusey and Bertrand, 1993). The implication is that fungicide protection may not be necessary beyond the second year for bark on the trunk, and beyond the third year for bark on the lower scaffold, which is one year younger.

SURVIVAL OF PEACH TREES IN FIELD MICROPLOTS

U.L. Yadava[1]

INTRODUCTION

Peach tree short life (PTSL) is primarily responsible for the drastic reduction in peach tree survival and rapid deterioration in orchard longevity in the southeastern United States (Ritchie and Clayton, 1981). This disease syndrome occurs more frequently in lighter soils, and is more prevalent on old orchard sites (Cohen and Gur, 1988; Gur and Cohen, 1988; Johnson, 1988). Various types of phytotoxins present in the soil have been implicated with other replant problems (Gur and Cohen, 1989; Patrick, 1955). Literature indicates that rootstock type imparts a significant effect on peach tree survival (Yadava and Doud, 1989; Yadava, 1992b). The rootstock effect is accentuated on PTSL prone sites.

For investigations that involve site influence on PTSL-related performance of trees under field conditions, it is rather difficult to have an old site with PTSL history directly adjacent to a new or non-PTSL (NPSL) planting site in the same orchard (Yadava, 1991; Yadava, 1992a). Thus, the concept of field microplots appears to be the most appropriate way to achieve this goal. Therefore, the purpose of this investigation was to monitor the survival and performance of 'Redhaven' peach trees in two experiments as influenced by: (a) planting soil (PTSL and NPSL) and rootstock type, and (b) the planting soil ratios and rootstock type.

MATERIALS AND METHODS

Planting Site: Two experimental plantings, A and B, containing 72 and 90 trees, respectively, in microplots of 55-gallon metal drums, were established side-by-side on the same orchard site at the Fort Valley State College Agricultural Research Farm, Fort Valley, GA. The metal drums with five 2-inch diameter holes in the bottom, were steam cleaned thoroughly, primed, and painted black to reduce rusting and to prolong their durability. The bottom holes in the drum were covered from inside by gluing a 3 inch x 3 inch patch of 60-mesh steel wire screen. Drums were placed over a 6 inch layer of coarse gravel that covered a drainage pipe laid in the bottom of 2 feet x 4 feet trenches. Inside the drum, a 4 to 6 inch layer of fine gravel was placed in the bottom and then the 'c' and 'b' layers of native soil recovered from the trenches, were placed over the gravel leaving 10 to 12 inches for top soil (the medium for planting trees) and the head space (Fig. 1).

Planting Soils: The top soil or the medium for planting trees in the microplot study designated as experiment A consisted of (1) non-peach tree short life (NPSL) soil or the native top soil recovered from the trenches, and (2) the top soil from a PTSL site near Byron, GA. In the microplot study designated as experiment B, the following soil mixtures were used: (a) 100% top soil from a PTSL site, (b) 75% PTSL + 25% NPSL soils, (c) 50% each of PTSL and NPSL soils, (d) 25% PTSL + 75% NPSL soils, and (e) 100% top soil from a NPSL site, which never had peaches grown in it before. The native top soil referred to here and onwards as 100% NPSL soil, was preplant fumigated using D-D soil fumigant.

Planting Material: Experiment A had 72 trees of 'Redhaven' cultivar of peach [*Prunus persica* (L.) Batsch] budded to Lovell and Nemaguard peach seedling rootstocks. In Experiment B there were 90 trees of 'Redhaven' peach either as budded scions on Lovell and Nemaguard peach seedling rootstocks or own-rooted 'Redhaven' trees propagated by hardwood cuttings (gratuitously received from Dr. Gary Couvillon, Department of Horticulture, University of Georgia, Athens). One-year-old trees were established in the microplots during spring 1984 using a randomized complete block design with 3 replications (the number of replications was limited by the inadequacy of material for microplots). Two trees per rootstock were

[1]Professor of Horticulture, Agricultural Research Station, School of Agriculture, Home Economics and Allied Programs, Fort Valley State College, Fort Valley, GA 31030-3298

randomized within the planting soils as the main plots. An above-ground drip system for irrigation and foam-pad covers to conserve moisture in the microplots, was installed during summer 1984. Cultural and orchard management practices used during this investigation, were those which are conventional in the Middle Georgia peach growing area.

Observations: Both experimental plantings were regularly observed for tree health and plant growth related performance. Though the data acquisition was spread over the entire year, observations for tree survival (enumeration of dead trees) were made during the month of December each year. In addition to delineating dying or dead trees, causes of tree mortality were also characterized and recorded.

Data Handling: The SAS program for PC version 6.03 was utilized for statistical handling of data. The statistical analysis of data was accomplished by ANOVA for balanced data, while mean separation was by the Duncan-Waller procedure. Harvard Graphics and Paint Brush (Windows) programs were employed in the preparation of color graphics and line diagrams.

RESULTS AND DISCUSSION

In experiment A, where NPSL soil was preplant fumigated with D-D, tree survival was significantly influenced by both soil and rootstock type. Throughout the 9-year observation period, a trend of greater tree survival in microplots containing NPSL soil than in those with PTSL soil, was noted. However, tree survival differences due to planting soil were significant only during a short period from 1990 to 1992 (Fig. 2A). Similar studies on microplots are not found in the literature, however, there is evidence that tree survival is greatly influenced by the replanting site (Johnson, 1988; Patrick, 1955). As seen in Figure 2 B, the survival of peach trees on Lovell seedling rootstock was greater than on Nemaguard seedlings, however the probability level of significance increased during last the three seasons. Superiority of Lovell seedlings as rootstock has been reported earlier (Ritchie and Clayton, 1981; Yadava, 1992b).

In experiment B, both the soil mixtures and rootstock type significantly influenced the survival of peach trees. Consistently, a greater percentage of trees survived in 100% NPSL soil while the lowest survival was for the 100% PTSL soil (Figure 2 C). Although the effects of other soil combinations were not clear cut, it was felt that greater tree mortality was associated with an increased ratio of PTSL soil in the mixtures. There is no information in the literature to support or contradict these results. Furthermore, it is quite logical to state that we can expect greater tree mortality with higher proportions of PTSL soil, because greater tree death occurs in PTSL soils than in new or non-PTSL soils. Redhaven peach trees on Lovell seedling rootstock invariably survived the longest followed by those budded on Nemaguard seedlings and the lowest on their own (Redhaven) roots, respectively (Fig. 2D). As early as in the fourth leaf, almost 55% of the own-rooted trees died compared to less than 10% on other rootstocks. Following the 1990 growing season, there was no significant difference between the survival of own-rooted Redhaven peach trees compared with those budded on Nemaguard seedling rootstock. Poor performance of clonal Redhaven peach trees on their own roots may have been due to a weak root system, since rooted cuttings do not have as numerous and anchoring roots as do seedlings.

In conclusion, both planting soil and rootstock type markedly influenced the survival of peach trees grown in field microplots during this nine-year study. Growth of surviving trees indicated that microplots were a good way to study impact of different soils in the same orchard. More trees died with greater frequency in PTSL than in NPSL soil or their combinations having greater proportions of PTSL soil. Additionally, it is confirmed that Lovell seedlings are a better rootstock for survival of peach trees on PTSL sites as compared with the other peach genotypes tested.

LITERATURE CITED

Cohen, Y. and A. Gur. 1988. Causes of soil sickness in replanted peaches. II. Causal agents for the specificity of the disease. Acta Hort. 233:33-36.

Gur, A. and Y. Cohen. 1988. Causes of soil sickness in replanted peaches. I. The role of cyanogenesis in peach soil sickness. Acta Hort. 233:25-31.

Gur, A. and Y. Cohen. 1989. The peach replant problem – some causal agents. Soil Biol. and Biochem. 21:829-834.

Johnson, C.E. 1988. Studies of replanting peach trees on old orchard sites. Proc. Southeastern Prof. Fruit Workers Conf., Vol. 3, Report # 6, 5 Pp.

Patrick, Z.A. 1955. The peach replant problem in Ontario. 2. Toxic substances from microbial decomposition products of peach root residue. Can. J. Bot. 33:461-486.

Ritchie, D.F. and C.N. Clayton. 1981. Peach tree short life: A complex of interacting factors. Plant Dis. 65:462-469.

Yadava, U.L. and S.L. Doud. 1989. Rootstock and scion influence growth, productivity, survival, and short life-related performance of peach trees. J. Amer. Soc. Hort. Sci. 114:875-880.

Yadava, U.L. 1991. Effect of planting soil, rootstock, and phytohormone sprays on peach tree survival in field microplots. HortScience 26:760

Yadava, U.L. 1992a. Short-life and non-short-life soil ratio and root type affect peach tree survival in field microplot. HortScience 27:638.

Yadava, U.L. 1992b. Influence of rootstock on twelve years performance of peach trees. Acta Hort. 315:317-326.

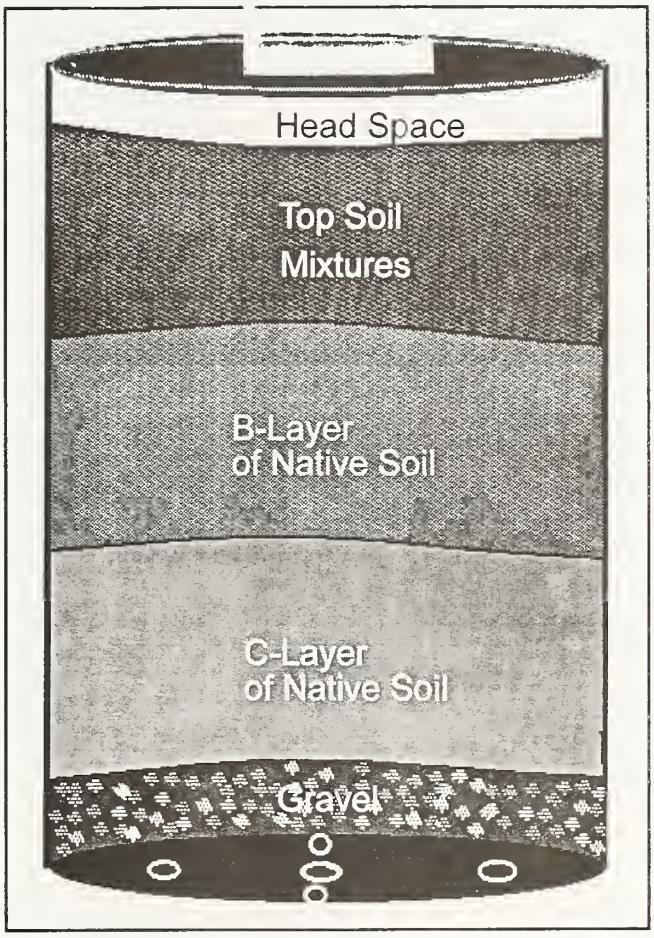


Figure 1. Soil profile within field microplot.

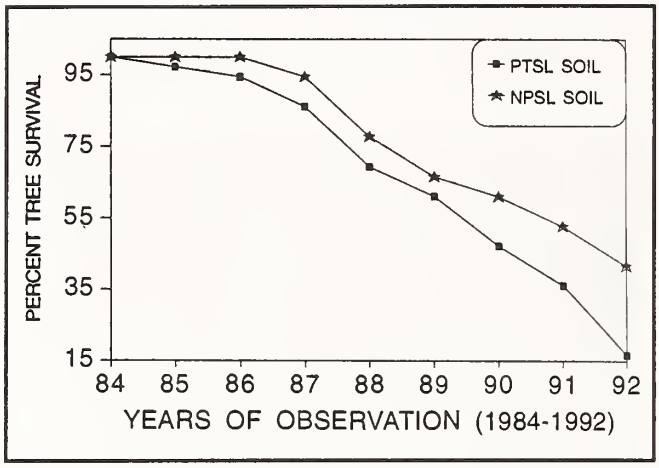


Figure 2-A. Influence of planting soil on peach tree survival in microplots.

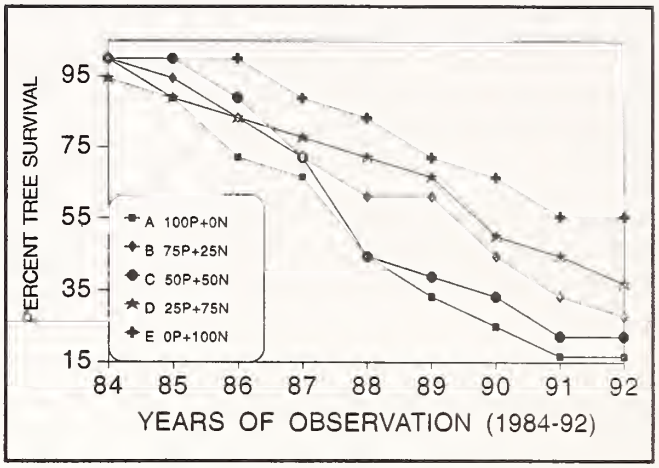


Figure 2-C. Influence of soil mixtures on peach tree survival in microplots (P = PTSL soil; N = NPSL soil).

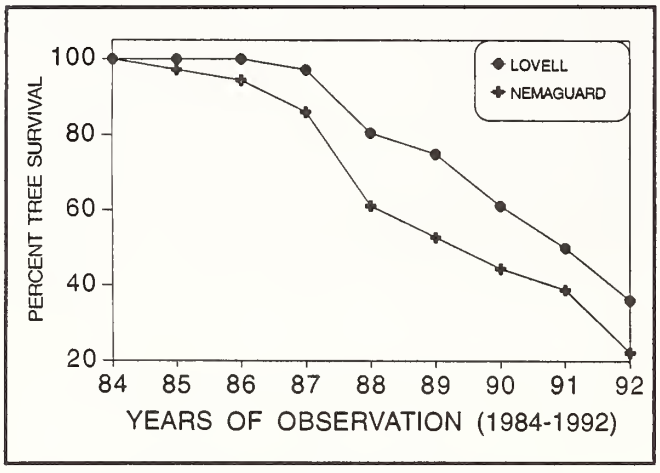


Figure 2-B. Influence of rootstock type on peach tree survival in microplots.

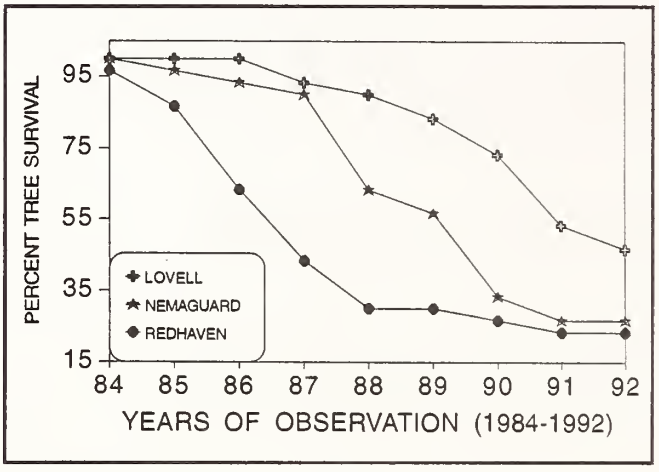


Figure 2-D. Influence of rootstock type on peach tree survival in microplots.

ENZONE AS A POSTPLANT NEMATICIDE FOR CONTROLLING RING NEMATODES AND BACTERIAL CANKER OF ALMOND ON PEACH ROOTSTOCK

W.K. Asai[1], N. Phillips, Jr.[2] and B.B. Westerdahl[3]

ABSTRACT

Ring nematode (*Criconemella xenoplax* = *Mesocriconema xenoplax*) and its association with bacterial canker (*Pseudomonas syringae*) has been a serious problem for stone fruit growers in the sandy soils of Central California. Since the loss of DBCP, there has not been an effective postplant treatment for these disorders, particularly for bearing orchards. In this study, Enzone (Tetrathiocarbonate; Unocal Chemical Company), was applied annually for three successive years to young almonds, beginning in the third leaf. The material was applied via basin flood irrigation. This orchard was having problems with bacterial canker and had extremely high ring nematode counts.

After the successive treatments with Enzone at 250 and 500 ppm a.i. in the basins, the high rate of Enzone resulted in a significant (P=0.05) decrease in ring nematode populations relative to the untreated check. The severity of bacterial canker was also reduced by the Enzone treatments and the production was increased.

MATERIALS AND METHODS

'Nonpareil'/Nemaguard almond trees were used in this study in an orchard growing on a Tujunga loamy sand. The orchard was in its third growing season at the time of the treatments and had experienced problems with bacterial canker and blast the previous two seasons. Pretreatment ring nematode counts showed very high populations (1,300-2,500 per 1,000 cm^3 soil). The samples were taken with an Oakfield probe with a 3/4 inch core to a depth of 18 inches. Five cores from each replicate were combined to make a sample. There were ten replications in this randomized complete block design. Samples were taken just prior to and approximately 30 days after treatments. Analysis were run at the U.C. Davis Department of Nematology using the sugar-flotation technique.

Treatments were applied in 10 ft x 10 ft basins around each tree. The soil was pre-wetted with water only, the day prior to treatments to insure uniform moisture in the soil profile. Treatments were applied in 160 gallons of water per tree in 1988 and in 500 gallons per tree in 1989 and 1990. The untreated check received only water, while the low rate was flooded with a 250 ppm a.i. solution and the high rate a 500 ppm a.i. solution. All treatments were mixed in a nurse tank and pumped into the individual basins.

The severity of bacterial canker infections was rated visually each spring after treatment application and classified based on the 10-point rating system developed by M. Norton,UCCE Farm Advisor, Merced County, California. Only the current season cankers were rated.

Yield responses also were measured each season after treatment application and were recorded as pounds of shelled almond meats per acre.

RESULTS AND DISCUSSION

The Enzone treatments resulted in significant differences in ring nematode populations between the untreated check and treatments in 1990 and as a three-year average (Table 1) (Fig. 1).

Although the severity of bacterial canker each year was not very high, the relative differences between the untreated check and the Enzone treatments were significant in 1989 and over the three year average (Table 2) (Fig. 2).

---

[1]Pomology Farm Advisor, University of California Cooperative Extension, Stanislaus County, 733 County Center II Court, Modesto, CA 95355

[2]Product Specialist, Unocal Chemicals and Minerals Division, 100 North 4th Street, Suite 4, Patterson, CA 95363

[3]Nematologist, University of California Cooperative Extension, UC Davis Department of Nematology, Davis, CA 95616

Of the parameters measured in this experiment, yield per acre responded the most to the Enzone treatments. Significant differences were recorded in two of the three years as well as the three year average (Table 3) (Fig. 3).

The data generated during this 3 year study indicates that Enzone can be an effective postplant nematicide for controlling ring nematodes and the associated bacterial canker in almonds grown on peach root. Other species of *Prunus* (apricot, peach, nectarine, plum) grown on peach root should show comparable results since the incidence and severity of bacterial canker and blast in those species is similar to that of almond. Whether or not Enzone will produce the same results when applied on a large scale with long (1,500 ft) irrigation runs needs to be determined.

Table 1. Percent change in number of ring nematodes/1000 cm^3 soil from pretreatmemt to postreatment sampling.

	1988[z]	1989[z]	1990	3 Year Average
Check	158.2	50.0	24.8 a	77.7 a
250 ppm a.i.	34.5	-15.2	-73.1 b	-17.9 b
500 ppm a.i.	-43.4	4.1	-58.1 ab	-32.5 b

[z]Indicates no significant differences in that year (P=0.05).

Table 2. Severity of bacterial canker.

	1989	1990[z]	1991	3 Year Average
Check	0.7 a	0.7	0.5	0.63 a
250 ppm a.i.	0.5 ab	0.7	0.2	0.47 ab
500 ppm a.i.	0.2 b	0.3	0.3	0.27 b

[z]Indicates no significant differences in that year (P=0.05).

Table 3. Yield in pounds of shelled meats per acre.

	1989	1990[z]	1991	3 Year Average
Check	780 a	1290	1202 a	1091 a
250 ppm a.i.	955 ab	1418	1352 ab	1242 b
500 ppm a.i.	1065 b	1560	1646 b	1424 c

[z]Indicates no significant differences in that year (P=0.05).

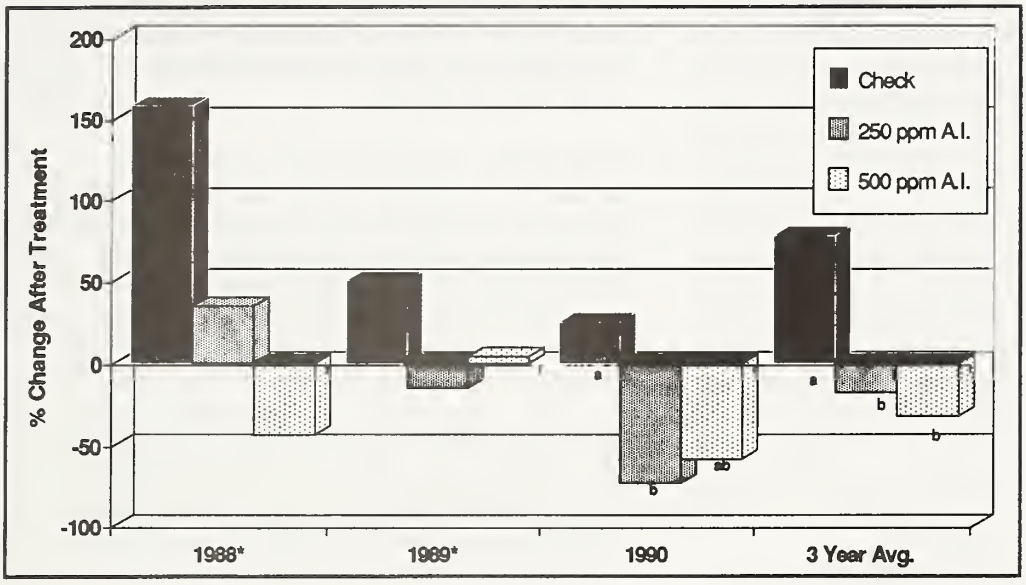


Figure 1. Ring nematode populations after treatment with Enzone. Means followed by the same letter are not significantly (P=0.05) different. (*=no significant difference in the year).

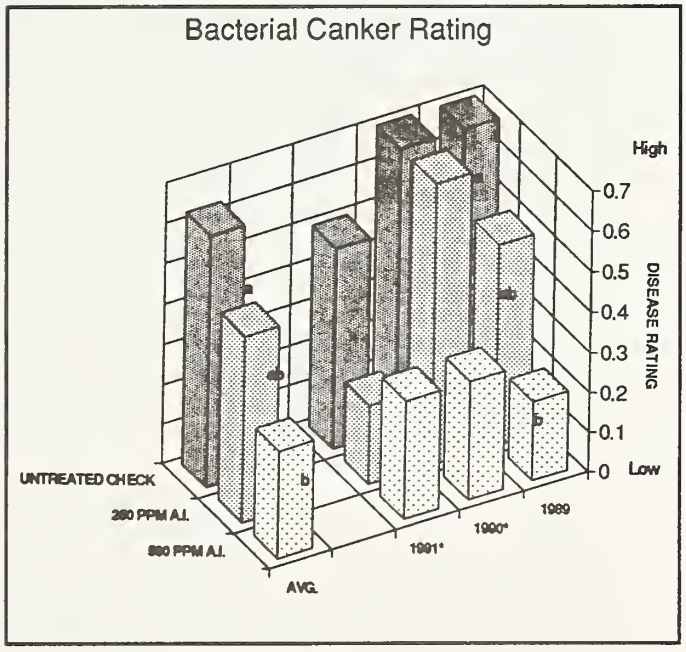


Figure 2. Enzone bacterial canker plot in almond. Means followed by the same letter are not significantly (P=0.05) different. (*=no significant difference in that year).

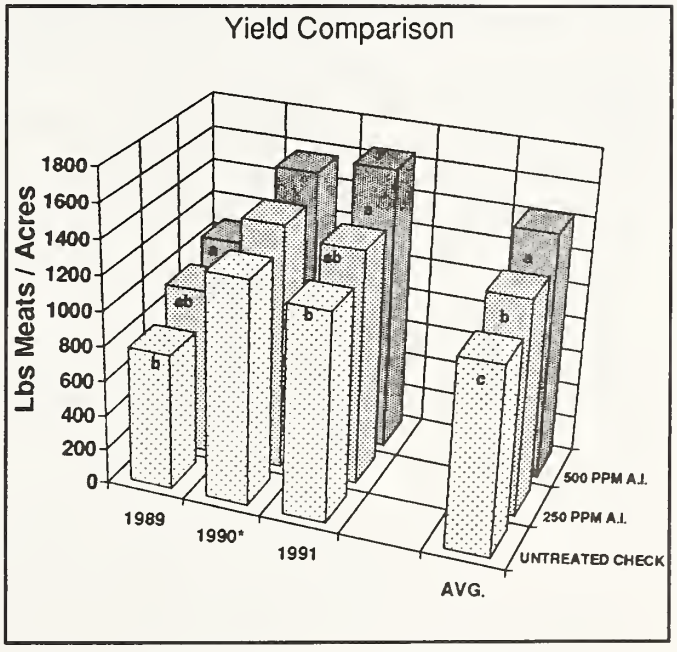


Figure 3. Enzone bacterial canker trail in almonds. Means followed by the same letter are not significantly (P=0.05) different. (*=no significant difference in that year).

1,3-DICHLOROPROPENE AS A POSTPLANTING NEMATICIDE FOR PEACH TREES

E.I. Zehr[1]

The chemical nematicide 1,3-dichloropropene (1,3-D, Telone II), is used extensively in South Carolina and elsewhere as a preplanting nematicide for control of the ring nematode *Criconemella xenoplax* (Raski) Luc and Raski (=*Mesocriconema xenoplax*) on peach trees [*Prunus persica* (L.) Batsch]. 1,3-D is registered only for preplanting use, and it is very effective for control of this nematode when correctly applied. Populations of *C. xenoplax* usually are controlled for about 2 years, but the nematode increases rapidly thereafter, and tree mortality often becomes substantial the fourth or fifth year after planting.

The need is acute for more effective control of *C. xenoplax* after planting. Fenamiphos (Nemacur) is the only nematicide registered for use on peaches after planting, and it is effective when used regularly year after year. However, the high cost of treatment discourages the use of fenamiphos, and most peach growers in South Carolina do not use it.

I began studying the use of 1,3-D as a postplanting treatment for peaches in 1979. Different rates of application and various kinds of application equipment have been studied. This manuscript summarizes these investigations.

MATERIALS AND METHODS

Orchards sites. Experiments were conducted at the Clemson University Sandhill Research and Education Center near Columbia, SC, on Lakeland sand (89% sand, 6% silt, 5% clay). On each experimental site, peaches had grown previously. Each was infested with *C. xenoplax* at the time of planting and was a chronic "short life" site. Peach trees planted on each site were on Lovell rootstock, purchased from commercial nurseries, planted 3.7 to 4.9 m apart with 7.3 m between rows. Bahiagrass sod served as groundcover between rows, and herbicides or a rotary tiller were used to control vegetation under the tree canopy.

Treatments. Various rates of 1,3-D (applied as Telone II from Dow-Elanco Chemical Co.) were compared with DBCP (1,2-dibromo-3-chloropropane) (Nemagon) or with fenamiphos (Nemacur) as standard nematicides. Other experimental materials included ethoprop (Mocap), carbofuran (Furadan), and sodium tetrathiocarbonate (Enzone-Unocal Corp.).

Nematicides were applied in bands 1.2 to 1.8 m wide on both sides of the tree row, at depths of 10 to 15 cm using chisels, except that Nemacur was applied as a surface spray or as granules that were incorporated 5 cm deep. Each treatment consisted of four or five replicates of four or five trees per replicate in a randomized complete block design.

Application equipment. Nematicides applied by chisel in experiments begun before 1988 were applied in cultivated soil by straight chisels 25 cm apart followed by a rotary tiller to seal the soil surface. Nematicides were dispensed to each chisel under pressure generated by a ground-driven John Blue pump. Those applied in 1988 or later were applied by a custom-built, PTO-driven apparatus consisting of 37.5-cm coulters each followed by a curved chisel of the same arc to deliver the nematicide at the desired depth. A steel-and-concrete press wheel (ca. 60 kg each) followed to seal the soil surface. Four coulters and press wheels 30 cm apart were mounted on a tractor-driven tool bar.

Nematode sampling. A sampling cone was used to collect cores of soil 2.5 cm diameter to a depth of 15 cm from beneath the tree canopy on each sampling date. Four or five subsamples (one per tree) were collected for each replicate and combined before extraction. Samples were stored in an ice chest until extraction. If dry when collected, soil was moistened to near field capacity 24 to 72 hours before extraction to improve efficiency (Lawrence and Zehr, 1978).

---

[1]Professor, Deparment of Plant Pathology and Physiology, Clemson University, Box 240377, Clemson, SC 29634-0377

Nematodes were extracted by elutriation (Byrd et al., 1976) followed by centrifugal-flotation (Jenkins, 1964). Nematodes were counted at 40x magnification.

RESULTS

Nematode control. In the first experiment, nematicides were applied in a 14-year-old peach orchard that had not been treated with nematicides previously. Two formulations containing 1,3-dichloropropene (Telone II and Shell D-D) were used. Both formulations suppressed populations of *C. xenoplax* -- no significant difference between the two was observed (Table 1). But Telone II suppressed numbers below the threshold of 50 per 100 cm^3 soil for a longer period of time. DBCP and Soilbrome also were effective postplanting treatments in this experiment.

In the second experiment, a uniform preplanting treatment of Telone II at 273 liters per hectare was applied in November, 1978. The first postplanting treatment was applied 25 November 1980, after *C. xenoplax* had become re-established in all plots (Table 2). Two rates of Telone II postplanting were compared -- 183 and 273 liters per hectare (20 and 30 gallons per acre). Both rates sharply reduced the initial population, and numbers remained below the threshold 50 per 100 cm^3 soil for up to 1 year for the 273-liter treatment, and almost as long for the 183-liter rate. In contrast, the Nemacur standard required three applications and more than 18 months to reduce the population to an acceptable level (Table 2).

In two later experiments, using more sophisticated application equipment, nematode suppression with Telone II at only 136 liters per hectare (15 gallons per acre) was satisfactory, but the results were difficult to evaluate because the initial population was low in the Telone II treatment in one experiment (Table 3) and numbers in the control were consistently low in the other (Table 4).

Growth response. Growth as measured by tree trunk diameters 25 cm above the soil line increased with most nematicide treatments, but trees treated with Telone II at 273 liters per hectare were no larger than controls (Table 5). Trees treated with this rate suffered chemical injury in roots, shown by reddish-brown necrosis extending 5 to 10 cm from the site of nematicide application. Injury to shoots was not apparent except perhaps in smaller tree size, but differences in size were not significant ($\underline{P} = 0.05$). Restriction of growth was not evident at the 183-liter rate (Table 5), and perhaps also at the 136-liter rate (Table 6), although a satisfactory basis for comparison is not available in the experiment begun in 1989 (Table 6).

Tree mortality. Fewer trees died in the Telone II-treated plots than in those treated with other nematicides or in nontreated plots (Tables 5 and 6). Trees that died manifested symptoms typical of the peach tree short life (PTSL) syndrome. Tree mortality was substantial in Nemacur-treated plots (Table 5).

DISCUSSION

Telone II appears to be an effective nematicide for use after planting peach trees for control of the ring nematode, *C. xenoplax*. Its effects are characterized by rapid decline of the nematode population and continued suppression of the nematode for up to 1 year after application. Effects are reflected in longer tree life in PTSL sites, and perhaps improved tree growth if rates used are not excessive.

1,3-D is a highly volatile chemical, and its effectiveness as a nematicide for *C. xenoplax* will depend upon creating an effective seal of the soil surface. The use of press wheels to seal the openings made by chisels appeared to be satisfactory, but perhaps more effective methods might be devised. The lowest rates possible for effective control are essential to minimize injury to roots, reduce the potential for ground water and air pollution, and to economize on the cost of materials for peach growers.

1,3-D and fenamiphos both are effective for use as postplanting nematicides for *C. xenoplax* on peach trees. 1,3-D has the advantage of prompting rapid decline of high nematode populations, whereas several applications of fenamiphos maybe necessary to achieve the same desired effect (Ritchie, 1984). Both are effective for preventing rapid increase of low populations. If 1,3-D is eventually registered for use as a postplanting nematicide on peaches, further experimentation would be needed to optimize rates and methods of application.

LITERATURE CITED

Byrd, D.W., Jr., K.R. Barker, H. Ferris, C.J. Nusbaum, W.E. Griffin, R.H. Small and C. Stone. 1976. Two semiautomatic elutriators for extracting nematodes and certain fungi from soil. J. Nematol. 8:206-212.

Jenkins, W.R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Dis. Rep. 48:692.

Lawrence, E.G. and E.I. Zehr. 1978. Improvement of techniques for determining populations of *Macroposthonia xenoplax* in dry soil. Phytopathology 68:1102-1105.

Ritchie, D.F. 1984. Control of *Criconemella xenoplax* and *Meloidogyne incognita* and improved peach tree survival following multiple fall applications of fenamiphos. Plant Dis. 68:477-480.

Table 1. Efficacy of certain postplanting nematicides for control of *Criconemella xenoplax* on peach, November 1980 - May 1982.

Treatment	Form. Rate ha^{-1}	*C. xenoplax* 100 cm^{-3} soil on: 25 Nov. (Pi)[z]	5 Feb.	24 Apr.	27 Aug.	4 Nov.	28 Jan.	5 May
DBCP 86E[y]	45 L	244	135	32	8	21	30	81
Vydate 2L[y]	18 L	196	260	174	308	---[w]	---	---
Vydate 2L[y]	27 L	81	246	156	166	---[w]	---	---
Nemacur 15G[x]	73 Kg	191	87	58	136	64	76	86
Nemacur 15G[x]	144 Kg	170	109	72	145	68	71	67
Telone II[y]	273 L	347	8	12	26	10	171	173
Soilbrome 90EC[x]	109 L	198	90	25	65	55	44	58
Shell D-D[y]	273 L	131	17	25	111	21	119	168
Control	0	314	222	128	247	102	132	262
L.S.D. (0.05)		N.S.	191	136	171	89	N.S.	N.S.

[z]Initial population.
[y]Applied in November 1980 only.
[x]Applied in November 1980 and again in November 1981.
[w]Sampling discontinued.

Table 2. Efficacy of certain postplanting nematicides for control of *Criconemella xenoplax* on peach, November 1982 - August 1984[z].

Treatment	Form. Rate ha-^{1}	*C. xenoplax* 100 cm^{-3} soil on: 3 Nov. (Pi)	20 Feb.	4 May	12 Jul.	21 Oct.	16 Feb.	14 May	13 Aug.
Telone II	183 L	140	75	16	28	71	16	97	182
Telone II	273 L	350	65	39	37	43	44	17	120
Nemacur 3 L (Fall)	30 L	232	141	89	83	188	98	118	171
Nemacur 3 L (Fall & Spring)	30 L[y]	436	429	157	159	150	66	89	36
Mocap 10G	436 Kg	129	111	127	201	316	299	271	209
Furadan 4E	30 L	112	109	38	260	100	317	314	222
Furadan 4E	14 L	134	79	42	98	111	142	202	111
Check	0	230	64	63	56	118	123	193	88
L.S.D. (P=0.05)		196	195	99	170	213	153	99	116

[z]Fall applications (all treatments) were made 4 November 1982 and 26 October 1983.
[y]Spring applications of Nemacur were 11 May 1983 and 19 April 1984.

Table 3. Suppression of *Criconemella xenoplax* in a 6-year-old peach orchard by postplanting nematicides in 1991[Z].

Treatment	Form. Rate ha^{-1}	*C. xenoplax* 100 cm^{-3} soil on: 12 Nov. (Pi)	30 May	9 Sept.	15 Nov.
ASC 66824 7.5 EC	12 L	208	95	45	292
ASC 66824 7.5 EC	18 L	126	80	293	548
ASC 66824 7.5 EC	24 L	147	152	284	349
Telone II	136 L	22	51	8	30
Enzone	908 L	158	93	125	137
Control	0	108	120	35	65
L.S.D. (P=0.05)			N.S.	N.S.	358

[Z]Nematicide applied in 1.5 to 2.0-meter bands on both sides of the tree row on 13 April 1991.

Table 4. Control of *Criconemella xenoplax* on peach by one preplanting and one postplanting application of Telone II or Enzone, 1988-1991[Z].

Treatment	Form. Rate ha^{-1}	*C. xenoplax* 100 cm^{-3} soil on: 25 Oct. (Pi)	1 Dec.	25 May	10 Aug.	15 Nov.	22 Feb.	9 May	24 Jul.	8 Nov.	25 Mar.	22 May
Telone II	136 L[Y]	44	16	2[W]	16	—	—	—	—	—	—	—
Telone II	272 L[X]	37	14	2[W]	46	7	0[W]	2	3	2	4	38
Enzone	908 L	32	21	17	31	16	4	21	2	3	7	75
Control	0	50	50	28	46	27	8	15	6	10	3	109

[Z]Preplanting treatment was applied 25 October 1988, and the postplanting treatment 15 November, 1989.
[Y]Preplanting treatment only. Sampling was discontinued after 10 August 1989.
[X]Postplanting rate was 136 L ha^{-1}.
[W]Significantly different from the control ($P = 0.05$) in paired comparisons.

Table 5. Growth response of peach trees to nematicide application and percent mortality in 1985[z].

Treatment	Form. Rate ha^{-1}	Trunk diameter (cm) Nov. 1982	Trunk diameter (cm) Feb. 1985	% Mortality
Telone II	183 L	3.6	6.0	7.1
Telone II	273 L	3.0	5.3	0.0*
Nemacur 3L (fall)	30 L	4.8	6.8	37.5
Nemacur 3L (fall & spring)	30 L	4.6	6.7	31.2
Mocap 10G	436 kg	4.2	6.9	71.4*
Furadan 4E	30 L	4.3	6.5	12.5
Furadan 4E	14 L	3.9	6.4	25.0
Check	0	3.0	5.1	12.5
L.S.D. (P=0.05)		N.S.	N.S.	46.1

*Significantly different ($\underline{P}$ = 0.05) from the fall and spring Nemacur standard.
[z]Nematicide treatments were applied 4 November 1982 and 26 October 1983. Spring applications of Nemacur were 11 May 1983 and 19 April 1984.

Table 6. Preplanting and postplanting effects of Telone II and Enzone nematicides on growth and mortality of peach trees in *Criconemella xenoplax*-infested soil.

Treatment	Form. Rate ha^{-1}	Trunk diameter (cm)[z]	% Mortality
Telone II	136 L[y]	4.5	24
Telone II	272 L; 136 L[x]	4.7	0
Enzone	908 L	4.2	16
Control	0	4.0	28
L.S.D. (P=0.05)		N.S.	28

[z]Trunk diameter measurements in March 1991, 2 yr after planting; and mortality in May 1992, 3 yr after planting.
[y]Preplanting treatment only.
[x]272-liter rate applied November 1988 before planting; 136-liter rate applied November 1989, after first year of growth.

CULTURAL CONTROL OF *CRICONEMELLA XENOPLAX* WITH PRE- AND POSTPLANT GROUND COVERS

A.P. Nyczepir[1], P.F. Bertrand[2], B.M. Cunfer[3], R.W. Miller[4], and R.C. Gueldner[5]

INTRODUCTION

Various small grains were evaluated for host suitability to the ring nematode, *Criconemella xenoplax* (=*Mesocriconema xenoplax*), under field and greenhouse conditions during 1986-89 (Nyczepir and Bertrand, 1990). Most small grain species tested were poor hosts, but one of the best plant species for suppressing the nematode in both the greenhouse and field tests was 'Stacy' wheat. In 1989, plans were formulated to evaluate the cultural control of the ring nematode in total peach orchard situations using Stacy wheat. The nematode management systems to be developed and evaluated include a) monitor the incidence of peach tree short life (PTSL) over time in the small grain plot previously planted to Stacy wheat and Lovell and Nemaguard peach for three consecutive years; b) evaluation of a one, two, and three-year rotation to test the effect of Stacy wheat (no trees present) as a nonchemical preplant control system for ring nematode prior to replanting the orchard to peach; and c) interplanting wheat around established peach trees as a nonchemical postplant control system.

[1]Research Nematologist, USDA-ARS, Southeastern Fruit and Tree Nut Research Laboratory, P.O. Box 87, Byron, GA 31008

[2]Extension Plant Pathologist, The University Georgia Cooperative Extension Service, P.O. Box 1209, Tifton, GA 31793

[3]Plant Pathologist, University of Georgia, Georgia Experiment Station, Griffin, GA 30223-1797

[4]Extension Plant Pathologist, Clemson University, Department of Plant Pathology, 206 Long Hall, Clemson, SC 29634-5732

[5]Research Chemist, USDA-ARS, Russell Agriculture Research Center, P.O. Box 5677, Athens, GA 30613

The various nematode management strategies were initiated in 1990 and the results after *two* years are reported herein.

MATERIALS AND METHODS

Small Grain Replant Study. The experiment was initiated in 1990 at the USDA station in Byron, Georgia. The study is being conducted on a Faceville sandy loam soil with a previous history of PTSL. The site had previously been planted to various small grains and two peach rootstocks since 1986 (Nyczepir and Bertrand, 1990). Preplant nematicide treatments were established in a split-plot design in peach plots using methyl bromide (561 kg/ha) in October 1989. In January 1990, six virus-free Loring/Nemaguard trees were planted per small grain, peach, and fallow subplot row. Subplots were replicated four times in a randomized complete block design with peach plots being split on fumigation. Trees were pruned in early February 1991, and postplant nematode samples first obtained in March 1991. Nematode population density will be monitored annually under trees in treatment plots in December and March. Incidence of PTSL will be checked in March of each year. Trees will be December-pruned beginning in 1991 to enhance development of PTSL.

Rotation Study. The rotation study is designed to evaluate the effect of a one, two, and three year wheat rotation (as a preplant management strategy) on the population density of *C. xenoplax* prior to replanting the orchard to peach. The peach trees on this test site have recently been removed due to high tree mortality from PTSL. Treatments will be established and centered over previous tree rows, since this is where nematode population density will be greatest. Treatments will include: 1) wheat-fallow rotation, where fallow represents weed control in order to eliminate alternate hosts for the nematode; 2) wheat-sorghum rotation, where a sorghum cultivar (NK-2660) that is a poor host to *C. xenoplax* will be rotated with wheat; and 4) peach alone, nonfumigated. Treatments will be established in plots ca. 19.5 m x 6.1 m (64 ft. x 20 ft.); with the 3-yr, 2-yr,

and 1-yr rotation treatments being initiated the first, second, and third year, respectively. This is to insure that when the test site is replanted entirely to peach after three years, all trees within all treatment plots are the same age. Also in the first year, the 1-yr and 2-yr rotation and peach plots will be planted entirely to Nemaguard peach seedlings when the 3-yr rotation treatments are initiated. This will provide a food source for the nematode, preventing a rapid decline in its population density while waiting to establish the latter two treatments. These trees will be removed upon initiation of the 1-yr and 2-yr rotations, respectively. Treatments will be replicated six times and arranged in a randomized complete block design. Population density of *C. xenoplax* and other plant-parasitic nematodes will be obtained prior to planting and monitored by annual postplant and preplant sampling every spring and fall immediately following wheat and sorghum harvest, respectively. Soil nutrient analysis will also be obtained annually to insure proper soil fertility as recommended by the Georgia Extension Service.

Wheat Interplanting Study. Continuous in-row planting of Stacy wheat around established peach trees will evaluate the potential of this suppressive plant as a nonchemical postplant nematode management strategy. Treatments will include wheat, herbicide alone, and herbicide+postplant nematicide split application (phenamiphos, 10 lb a.i./A). The wheat treatment will surround the trunk ca. 1.5 m (5 ft.) on either side of existing four-year-old peach trees (4.9 m x 6.1 m spacing) on Nemaguard rootstock. Treatments will consist of five trees per subplot with the inner three trees serving as test trees. Guard rows will be present on either side of the test rows. Treatments will be replicated eight times in a randomized complete block design. Wheat will have to be reestablished each fall since it dies annually. Wheat seed will be broadcast under the tree using a Vicon seeder-spreader at a rate of 2 bu/A to soil that has been previously shallow-tilled. Phenamiphos will be applied (Field-Master Walkover sprayer) as a fall-spring split application at rates recommended by the Georgia Extension Service. Population density of *C. xenoplax* and other plant-parasitic nematodes will be obtained annually prior to planting wheat, followed by postplant sampling in late-spring when wheat is normally harvested. Tree mortality will be monitored for the duration of this study, since trees on this test site are at a critical age of succumbing to PTSL.

Root Exudate Study. The attraction and/or repulsiveness of 'Stacy' wheat and 'Nemaguard' peach root extracts were studied under laboratory conditions. The test extracts were prepared by soaking 4.6 gm fresh weight of roots in sterile distilled water for 17-24 hr in darkness. Extracts were then filtered, and the filtrates brought to dryness via freeze-drying. Test extracts were then redissolved by adding 10 ml sterile distilled water to the beaker. Petri dishes (60 x 15 mm) containing a rectangular strip (ca. 56 x 8 mm) of 1.5 % water agar were used as the test system for this investigation. At either end of the agar strip, a 6-mm-dia Whatman #2 paper disk containing the root extract (100 ul) treatment was placed on top of the agar. Seven actively moving nematodes were then hand-picked and placed in a drop of water (0.005 ml) in the center of the agar strip. The nematode was challenged with the following treatment combinations per dish, they included peach/water, peach/wheat, wheat/water, and water/water. Treatment combinations were replicated four times and the test was repeated once. Nematode attraction toward the test extracts was a measure of the percent of selecting nematodes weighted by the total distance (mm) the selecting nematodes moved after ca. 20 hr.

RESULTS

Small Grain Replant Study. The April 1992 postplant *C. xenoplax* counts indicate that the nematode population density was greater ($P \leq 0.05$) in nonfumigated peach plots than in fumigated peach, fallow or Stacy wheat plots after two growing seasons (Table 1). Incidence of PTSL was detected in all treatment plots,

however, greatest ($P \leq 0.01$) incidence of PTSL and tree death occurred in the two nonfumigated peach plots previously planted to Lovell and Nemaguard (Table 1). No significant differences in tree mortality was detected among the fumigated, Stacy wheat or fallow treatments. Results indicate that planting Stacy wheat for three consecutive years is still comparable to preplant fumigation with methyl bromide in reducing incidence of PTSL in 2-year-old Loring/Nemaguard peach trees. It should be noted that ring nematodes were detected in all plots in the spring of 1992.

Rotation Study. *Criconemella xenoplax* was detected in both peach and Stacy wheat plots in June 1991; six months after planting (Table 2). However, the number of ring nematodes was lower ($P \leq 0.01$) in plots planted to wheat than Nemaguard peach. After two complete rotations of wheat (see June 1992), ring nematodes are still detected in these plots, but their population density is significantly lower in both the wheat/fallow and wheat/sorghum rotations as compared to continuous peach. Results indicate that wheat/fallow or wheat/sorghum rotations do not reduce the *C. xenoplax* population density to nondetectable levels after one or two year rotations with wheat.

Wheat Interplanting Study. Postplant nematode sampling of treatment plots indicate that interplanting Stacy wheat around 5-year-old Juneprince/Nemaguard trees is not reducing the population density of *C. xenoplax* after two years compared to the other treatments (Table 3). It should also be noted that postplant application of phenamiphos is not affecting the nematode population density at this time.

Root Exudate Study. Results indicate that wheat was not repulsive to the ring nematode, since more nematodes migrated toward wheat when challenged with wheat/water (Fig. 1.). However, peach was more attractive to *C. xenoplax* than wheat when challenged with peach/wheat. The peach root extract was more ($P \leq 0.05$) attractive to the ring nematode than wheat or water (Table 4). There was no difference in nematode attraction between water and wheat.

CONCLUSIONS

Small Grain Replant Study. Stacy wheat is comparable to preplant fumigation in reducing the incidence of PTSL after two years.

Rotation Study. Wheat/fallow and wheat/sorghum rotations significantly reduced the ring nematode population density as compared to continuous peach after two years, but nematodes are still detectable at low levels.

Wheat Interplanting Study. Stacy wheat is not lowering the ring nematode population around established trees after two years.

Root Exudate Study. The Stacy wheat root extract did not have a repulsive effect on the ring nematode, but appears to be a nonhost.

In conclusion, it appears that Stacy wheat is demonstrating more potential as a preplant rather than a postplant management strategy of the ring nematode and PTSL after two years. Studies are still in progress.

LITERATURE CITED

Nyczepir, A. P. and P. F. Bertrand. 1990. Host suitability of selected small grains and field crops to *Criconemella xenoplax*. Plant Dis. 74:698-701.

Table 1. Postplant population density of *Criconemella xenoplax* (Cx) and incidence of PTSL in small grain plot replanted entirely to Loring/Nemaguard peach.

Previous plant species	Cultivar	Fumigation[z]	Number of Cx per 100 cm^3 soil		Incidence of PTSL	
			Mar. 1991	April 1992	May 1991 (%)	May 1992 (%)
Peach	Nemaguard	No	134 a[y]	310 a	46 a[x]	50 a
		Yes	0 b	18 bc	8 b	8 b
	Lovell	No	108 a	138 a	58 a	67 a
		Yes	0 b	4 c	8 b	13 b
Wheat	Stacy	---	0 b	49 b	4 b	13 b
Fallow	---	---	0 b	39 bc	8 b	13 b

[z]Preplant fumigation=MBr at 561 kg/ha.
[y]Means separation by Duncan's Multiple range test ($P \leq 0.05$).
[x]Means separation by Fisher's ($P \leq 0.01$) Exact test.

Table 2. Mean population density of *Criconemella xenoplax* (Cx) in wheat and peach rotation plot.

Rotation Scheme	Number of Cx per 100 cm³ soil, June 1991	June 1992
Peach	154 a[z]	585 a[y]
Wheat/Fallow	41 b	---
Wheat/Fallow/Wheat	---	30 b
Wheat/Sorghum/Wheat	---	20 b

[z]P ≤ 0.01 according to F-test.
[y]P ≤ 0.05 according to DMRT.

Table 3. Mean population density of *Criconemella xenoplax* (Cx) around 5-yr-old Summergold/Nemaguard peach interplanted with 'Stacy' wheat.

Treatment	Rate	Number of Cx per 100 cm³ soil, June 1991	June 1992
Wheat	2 bu/A	1035	519
Phenamiphos	10 lbs. ai/A	713	343
Herbicide strip (control)	---	575	551

Table 4. Attractiveness of peach and wheat root extracts to *Criconemella xenoplax* (Cx).

Root Extract	Cx mobility rating[z]
Peach	4.83 a[y]
Wheat	1.91 b
Water	0.28 b

[z]Proportion of Cx selecting a given stimulus multiplied by total distance (mm) selecting Cx moved.
[y]P ≤ 0.05 (DMRT).

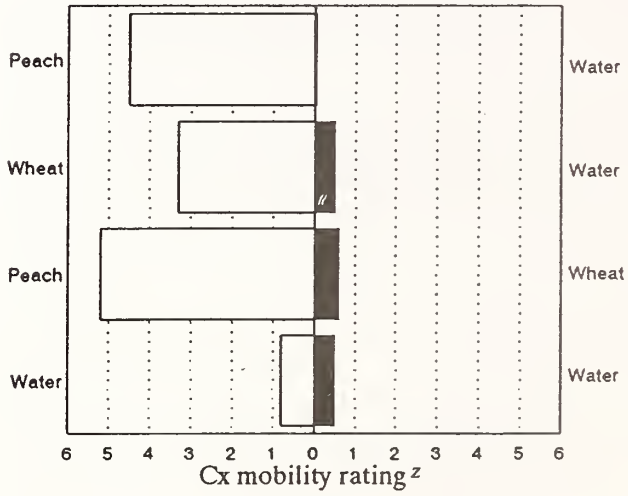


Figure 1. Attraction of *Criconemella xenoplax* (Cx) to various paired root extract and water combinations [z=proportion of Cx selecting a given stimulus multiplied by total distance (mm) selecting Cx moved].

INHIBITION OF *CRICONEMELLA XENOPLAX* BY *PSEUDOMONAS AUREOFACIENS*

S.W. Westcott III, D.A. Kluepfel and S.P. Ingold[1]

INTRODUCTION

It is widely believed that soils suppressive to plant-parasitic nematodes are ideal sites for exploration to find new biological control agents. Peach orchard sites suppressive to *Criconemella xenoplax* (Raski) Luc and Raski [=*Mesocriconema xenoplax* (Raski) Loof & de Grisse] have been discovered, characterized, and fluorescent pseudomonads that affect nematode population growth have been isolated (Kluepfel et al., 1993). From among 290 pseudomonads isolated from the suppressive site, seven strains of *Pseudomonas aureofaciens* affected nematode population growth in greenhouse tests (Kluepfel et al., 1993).

We examined two potential modes of action, aversion of nematodes to bacteria on roots and inhibition of egg hatch. One strain, *P. aureofaciens* BG33CL1R, did not affect nematode migration to or on roots but did affect egg hatch. A partial characterization of this strain's ability to inhibit egg hatch has been reported previously (Westcott and Kluepfel, 1992).

MATERIALS AND METHODS

Pseudomonas aureofaciens BG33 and eight other fluorescent pseudomonads had been isolated from peach roots collected from a soil suppressive to *C. xenoplax* (Kluepfel et al., 1993). A genetically modified derivative of BG33, designated BG33CL1R, had been created to facilitate tracking in subsequent experiments. BG33CL1R is resistant to rifampicin at 100μg/ml and contains the lacZY construct that allows it to cleave the chromogenic dye, 5-bromo-4-chloro-3-indoleβ-D-galactopyranoside (X-gal) (Barry, 1988). Strains of *Escherichia coli* DH5α, *Rhizobium fredii* USDA257 and *R. leguminosarum* were available from local culture collections.

Bacteria were grown on an appropriate agar medium for 24 hours at 26 C, cells were scraped from agar, and suspended in sterile distilled water for inoculum. Inoculum concentration was standardized spectrophotometrically, and where indicated, the CFU/ml were determined by standard dilution-plating techniques. *Pseudomonas* spp. were grown on Pseudomonas Agar F (PAF, Difco, Detroit, MI). *Escherichia coli* was grown on Luria-Bertani agar (LBA) which contains 10 g Bacto tryptone (Difco, Detroit, MI), 10 g NaCl, 5 g yeast extract, and 15 g agar per liter. *Rhizobium* spp. were grown on yeast-extract-mannitol agar (YEM).

Distribution of BG33CL1R and nematodes on peach roots. Peach seedlings (*Prunus persica* L. Batsch. 'Nemaguard') were grown in plastic growth pouches (Northrup King Co., Minneapolis, MN). A cotton string was inserted through slits 2 cm up from the bottom of pouches and kept wet by contact with water in a plastic pan located directly under the pouches. This supplied water to the paper wick inside pouches. Plants were fertilized weekly with 5 ml of Hoagland's solution with K_2NO_3 and $CaNO_3$ as the sources of nitrogen (Hoagland and Arnon, 1950). Fertilizer solution was applied to the side of the paper wick opposite from that on which the roots were growing to avoid washing microorganisms down the roots.

Pseudomonas aureofaciens BG33CL1R from a 12-hr culture were suspended in water, and adjusted to ca. 1×10^9 cells/ml spectrophotometrically. Peach seedlings were soaked in this bacterial suspension or sterile water for 30 minutes. Plants were then transferred to pouches and incubated at 23 C under fluorescent lights (14-hour photoperiod). Peach seedlings soaked in water were planted as controls.

---

[1]Visiting Assistant Professor, Assistant Professor and Research Specialist, Department of Plant Pathology and Physiology, 120 Long Hall, Box 340377, Clemson University, Clemson SC 29634-0377. Funded in part by USDA ARS Special Grant 91-34'26-5914. We thank Peter Burrows for advice on statistics and Lynn Luszcz for technical assistance.

First experiment. Four plants each were treated with bacteria or water before placement into pouches as described above. *Criconemella xenoplax* from greenhouse cultures was added to all plants at the top of the root system 9 days after placement in pouches (1,000 adults and juveniles per plant in 0.5 ml of water). A sampling of 2-4 plants was examined weekly to determine if nematodes were feeding and where the majority were located. Plants were harvested 11 weeks after bacterial inoculation. At harvest, five 1-cm pieces of lateral root were selected randomly for detection of bacteria. These pieces were comminuted in sterile water and populations of bacteria were estimated by dilution-plating of the resultant suspension on PAF containing rifampicin (100 μg/ml). To determine the distribution of nematodes, pouches were cut into sixteen 3-cm squares. Nematodes were washed off each square and counted. Roots were removed from the paper wick and weighed.

Second experiment. Four plants were treated with bacteria and eight plants were treated with water before placement in pouches as described above. *Criconemella xenoplax* from greenhouse cultures was added to all plants at the top of the root system 14 days after placement in pouches (540 adults and juveniles per plant in 0.9 ml of water). Plants were harvested 12 weeks after bacterial inoculation. Pouches were cut into three horizontal strips separating the top, middle and bottom portion of the root system. Nematodes were removed from each strip as described above. Roots were removed from the paper wick and weighed. Roots were then comminuted in 2 ml of sterile water and populations of bacteria were estimated by dilution-plating of the resultant suspension on PAF containing rifampicin (100 μg/ml) and cycloheximide (100 μg/ml). Representative colonies were plated on media containing X-gal.

Third experiment. BG33CL1R scraped from agar cultures was applied by smearing cells on the tap root of three 2-week-old seedlings grown in pouches. *Criconemella xenoplax* collected from monoxenic cultures grown on crimson clover root explants were placed on 8-mm diameter filter disks. Immediately after application of bacteria, these disks, with ca. 2,500 nematodes, were placed near the top of the root system in a position such that the nematodes were separated from roots by a visible population of bacteria. The movement of nematodes was monitored with a stereomicroscope on a daily basis for 1 week.

Egg-hatch Assays

Nematode eggs were collected as previously reported (Westcott and Burrows, 1991). Twelve to 20 gravid females of *C. xenoplax* were transferred by hand into 3 ml of distilled water in a 35-mm-diameter plastic petri dish and allowed to deposit eggs in the dark at 26 C for 24 hours. After egg deposition, females were removed, the eggs were counted, and then treated by addition of bacterial suspensions in water prepared as described above or addition of distilled water as a control. The concentrations of bacteria varied with experiment, but were above 3×10^7 in every case. Each dish contained 20-90 eggs. The numbers of hatched second stage juveniles were tallied 2 weeks after deposition. The proportion of eggs hatched was adjusted to a fraction of the respective water control to allow for comparisons between experiments and statistical analysis.

Bacterial screen. Ten fluorescent pseudomonad strains and three other species of bacteria, *Escherichia coli* strain DH5α, *Rhizobium fredii* strain USDA257, and *R. leguminosarum*, were used individually in the egg-hatch assay to determine their ability to kill *C. xenoplax* eggs. Nematode eggs were treated with bacterial suspensions immediately after removal of females from petri dishes. Each experiment included a positive control, an effective dose of BG33CL1R, and a negative control, a water treatment. Experiments were repeated at least twice.

Dose-response assays. Bacterial inoculum was prepared as described above for application in the egg-hatch assay. To establish a dose-response relationship, an inoculum from a range of five concentrations of BG33CL1R or water

as a control was added to petri dishes containing eggs. The experiment was repeated 20 times to achieve a thorough coverage of the transition between ineffective and effective dosage. Results from these were combined, and a logistic model was fitted by maximum likelihood methods weighted by the number of observations per treatment. The model provided an estimate of the median effective dosage.

Duration of egg sensitivity. Nematode eggs were treated with effective concentrations of *P. aureofaciens* BG33CL1R (ca. 2×10^8 CFU/ml) or water immediately after removal of females from petri dishes and at one day intervals up to 7 days after eggs were deposited for an egg-hatch assay. Appearance of eggs before and after treatments was recorded photographically. The proportion of eggs hatched was determined 2 weeks after eggs were deposited. This experiment was repeated twice.

RESULTS

Distribution of BG33CL1R and Nematodes on Peach Roots

First experiment. BG33CL1R was not detected on the random sampling of roots selected from plants grown in pouches in the first experiment. There were no differences in the distribution of nematodes on roots regardless of bacterial treatment. Therefore, the results for the two treatments were combined for presentation (Fig. 1 and 2). The nematode population was distributed predominately in the bottom row of pouches where the majority of young roots were found (Fig. 1). Observations of the roots during the incubation indicated that the nematodes had migrated down the root system, feeding on the way. Eggs were deposited at each level. By the end of the experiment, the highest proportion of root fresh weight was found in the top row of column 3 where the stem emerged (Fig. 2). This was comprised mostly of the primary tap root and there were few young lateral roots in this sector. Most of the young roots and a large portion of the nematodes observed feeding were at the bottom of the pouch.

Second experiment. BG33CL1R was detected on roots and in nematode wash water only form the top row of growth pouches. BG33CL1R was not detected in either of the two lower levels of growth pouches. The average bacterial population for the four root systems harvested 12 weeks after inoculation was $4.44 \pm 4.3 \times 10^4$ CFU/root. The proportional distributions of the nematode populations (Fig. 3) and root weights (Fig. 4) were similar to that seen in the previous experiment. No differences in the proportional distributions of root weights or nematode populations were discovered between the plants treated with bacteria and those treated with water.

Third experiment. Many nematodes were observed moving into and through deposits of bacteria on and near roots where bacteria were applied. Nematodes were not seen feeding on roots in this area possibly because the application process or the bacteria themselves appeared to have injured young lateral roots that are common feeding sites. However, nematodes did migrate to young healthy roots and begin feeding during the observation period. Nematodes in the bacterial deposits did not appear to be inhibited from moving nor did they appear to be avoiding the bacteria.

Egg-hatch Assays

Bacterial screen. Only BG33 and BG33CL1R inhibited egg hatch at the range of concentrations tested (Table 1). In all treatments receiving bacteria, egg hatch was delayed approximately 1 day with the proportion of eggs hatching slightly depressed as compared with water controls.

Dose-response assays. In water control dishes without added bacteria, 51 ± 24% of eggs hatched. The medium effective dose (μ) was estimated to be 4.8×10^7 CFU/ml of BG33CL1R. Estimates for effective dosages to kill 5%, and 95% of eggs were 1.0×10^7, and 2.4×10^8 CFU/ml, respectively.

Duration of egg sensitivity. Eggs were sensitive to application of BG33CL1R up until the time when the second-stage juvenile had formed in the egg (Fig. 5). In water controls, formation of stylets, which indicates development of the second-stage juvenile, was first observed ca. 6.5 days after egg deposit. Egg development appeared to cease soon after application of bacteria. Some nematodes that were killed when bacteria were added late in their development (after 5.2 days) produced stylets before dying (Fig. 6). The internal cellular integrity of most eggs exposed to effective concentrations of BG33CL1R was completely lost by the end of the 2-week incubation. However, egg shells appeared to be uncompromised. Adults and hatched second-stage juveniles survived in BG33CL1R suspensions for 2 weeks as evidenced by continued movement.

DISCUSSION

Pseudomonas aureofaciens BG33 was isolated from peach roots collected from a soil suppressive to *C. xenoplax* (Kluepfel et al., 1993). In greenhouse tests, BG33 and its genetically modified derivative BG33CL1R suppressed nematode population growth by more than 50% in most tests (Kluepfel et al., 1993). In plastic growth pouches, nematodes moved through bacteria to reach roots and there was no apparent injury to nematodes incubated in bacterial suspensions. Therefore, BG33CL1R does not affect activity of adults and juveniles in a way that might explain the inhibition of nematode population growth by this strain.

Although six other strains of *P. aureofaciens* also suppressed nematode population growth (Kluepfel et al., 1993), four of these did not affect egg hatch in our study (A1-10, A5-4, G2-6, H1-7); two remain untested. An additional three strains of fluorescent pseudomonads also did not inhibit egg hatch (BA5, E2-7, G2-2). Two of these inhibited *C. xenoplax* population growth in the greenhouse and one, G2-2, stimulated population increase (Kluepfel and McInnis, 1993, unpublished). Three additional bacteria, *E. coli, R. leguminosarum*, and *R. fredii*, caused no dramatic effect on egg hatch. These observations suggest that the egg kill observed with BG33CL1R does not result from general septic conditions in the egg hatch assay.

Compounds toxic to nematodes are produced as a normal process of cellular metabolism. For example, ammonia that is released by bacteria growing on nitrogen rich media is toxic to most nematode species (Rodriguez-Kabana, 1986). This mechanism would be expected to affect eggs, juveniles and adults. The fact that only BG33 and BG33CL1R killed eggs while the other strains did not, supports the hypothesis that a more specific factor is involved.

A large number of known metabolites produced by fluorescent pseudomonads are toxic to other microorganisms (Schippers et al., 1987). Some of these may be toxic to plant-parasitic nematodes (Becker et al., 1988; Kloepper et al., 1992), and a few may be toxic to specific stages of development. As yet little is known about how these toxins cause injury to nematode eggs and the involvement of toxins with egg kill by BG33CL1R awaits proof.

Development of eggs stopped soon after bacterial treatment which suggests rapid injury to treated eggs. Only stages of the egg that developed prior to formation of the second-stage juvenile were sensitive to the bacteria. Since adults and juveniles were insensitive, it appears that the nematode cuticle, and not the egg shell, is a selective barrier to the egg-kill factor. First stage juveniles were sensitive, indicating that the cuticle of this stage may not be an effective barrier. Alternatively, nematodes may be sensitive to the bacteria during the first molt.

Discovery of BG33 offers the opportunity to identify specific factors active against *C. xenoplax* eggs. If these factors prove to be unique compounds, they may be utilized in a number of ways within control programs for *C. xenoplax*. It may be possible that this factor will affect a variety of other plant-parasitic nematodes and this could lead to further utility in control systems. Further efforts are in

progress to isolate and characterize the egg-kill factor and the genes responsible for its production.

LITERATURE CITED

Barry, G.F. 1988. A broad-host-range shuttle system for gene insertion into the chromosomes of Gram-negative bacteria. Gene 71:75-84.

Becker, J.O., E. Zavaleta Mejia, S.F. Colbert, M.N. Schroth, A.R. Weinhold, J.G. Hancock and S.D. van Gundy. 1988. Effects of rhizobacteria on root-knot nematodes and gall formation. Phytopathology 78:1466-1469.

Hoagland, D.R. and D.I. Arnon. 1950. The water-culture method for growing plants without soil. CA Agr. Expt. Sta. Circ. 347.

Kloepper, J.W., R. Rodriguez-Kabana, J.A. McInroy and R.W. Young. 1992. Rhizosphere bacteria antagonistic to soybean cyst (*Heterodera glycines*) and root-knot (*Meloidogyne incognita*) nematodes: Identification by fatty acid analysis and frequency of biological control activity. Plant Soil 139:75-84.

Kluepfel, D.A., T.M. McInnis, and E.I. Zehr. 1993. Involvement of root-colonizing bacteria in peach orchard soils suppressive of the nematode, *Criconemella xenoplax*. Phytopathology 83. (In press).

Rodriguez-Kabana, R. 1986. Organic and inorganic nitrogen amendments to soil as nematode suppressants. J. Nematol. 18:129-135.

Schippers, B., B. Lutenberg and P.J. Weisbeek. 1987. Plant growth control by fluorescent pseudomonads, Pp. 19-39. In: I. Chet (ed.) Innovative Approaches to Plant Disease Control. New York: J. Wiley and Sons.

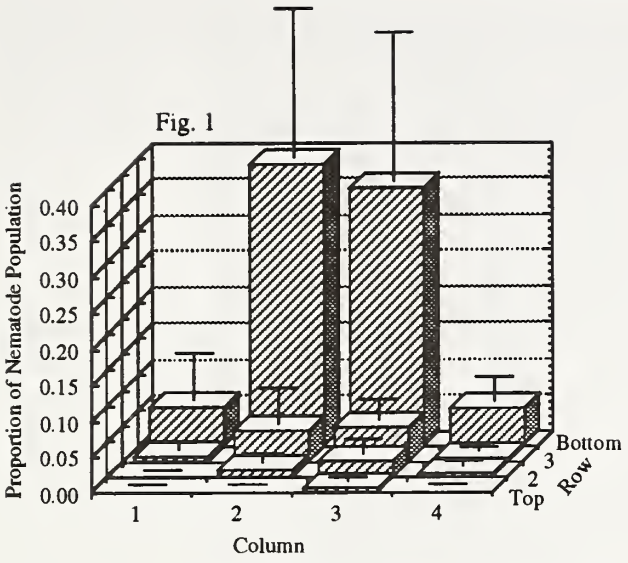
Westcott, S.W. and P.M. Burrows. 1991. Degree-day models for predicting egg hatch and population increase of *Criconemella xenoplax*. J. Nematol. 23:386-392.

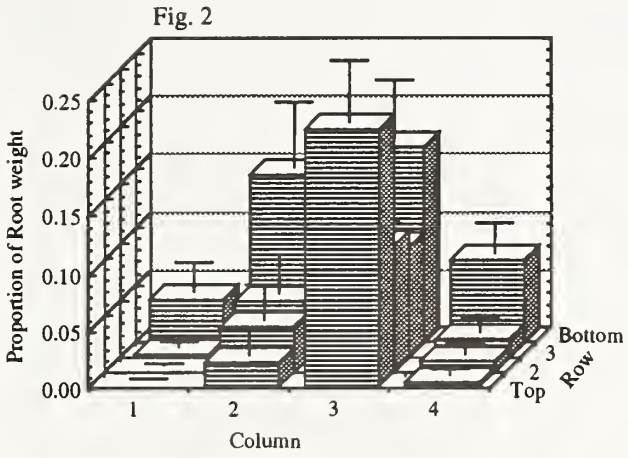
Westcott, S.W. and D.A. Kluepfel. 1992. Inhibition of *Criconemella xenoplax* egg hatch by a strain of *Pseudomonas aureofaciens*. J. Nematol. 24:626.

Table 1. Adjusted proportion egg hatch by *Criconemella xenoplax* when eggs were treated with different strains of bacteria.

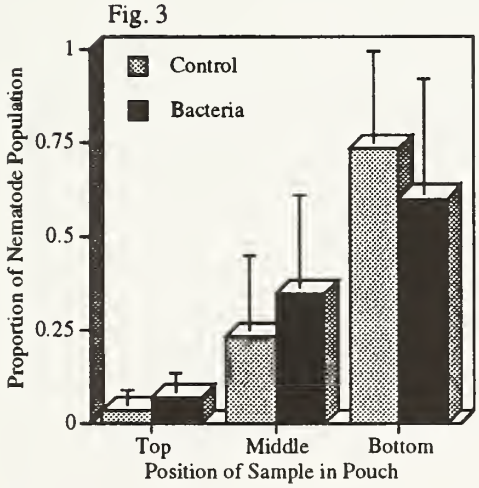
Strain	10^7 CFU[z]	N[y]	Proportion Hatched[x]
Pseudomonas aureofaciens			
BG33	3.6 - 26	20	0.01 ± 0.03
BG33CLR	1.8 - 99	47	0.15 ± 0.32
A1-10	6.2 - 21	17	0.94 ± 0.14
A5-4	7.6 - 13	6	0.91 ± 0.12
G2-6	7.3 - 69	12	0.77 ± 0.17
H1-7	9.0 - 11	6	0.78 ± 0.20
Fluorescent pseudomonads			
A1-3	8.4 - 51	17	0.85 ± 0.19
BA5	6.8 - 11	6	0.97 ± 0.06
E2-7	11.0 - 80	17	0.83 ± 0.22
G2-2	11.0 - 62	17	0.84 ± 0.18
Escherichia coli	3.4 - 40	27	0.76 ± 0.25
Rhizobium fredii	5.7 - 47	6	0.93 ± 0.12
R. leguminosarum	ND[w]	15	0.82 ± 0.17

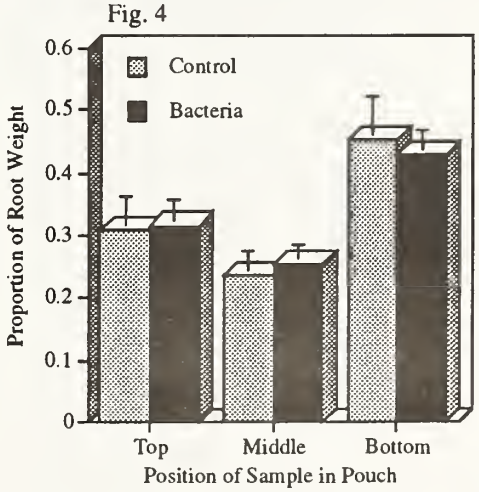
[z]Range of initial concentrations of bacteria in suspension around nematode eggs as determined by dilution and plating.
[y]Number of dishes of eggs included in average proportion hatched.
[x]Mean proportion and standard deviation of eggs hatched after 2 weeks. Values have been adjusted to a fraction of control hatch in respective experiments.
[w]Although the range of CFU was not determined, bacterial concentrations in these dishes were similar to those in other treated dishes as determined by turbidity.





Figures 1-2. The plot represents 16 sectors corresponding to 3-cm squares covering the entire area of plastic growth pouches. The top and bottom rows are marked and the stem emerged from column 3. Before planting in pouches, four peach seedlings were treated by immersion in a suspension of *Pseudomonas aureofaciens* BG33CL1R (ca. 1 x 10^9 cells/ml), and three plants were treated as controls in sterile distilled water. *Criconemella xenoplax* was applied to all seedlings. Bacteria were not detected from a random sampling of lateral roots at harvest and so the two treatments were combined for presentation. Fig. 1) Proportion of *Criconemella xenoplax* population found at different positions within growth pouches containing Nemaguard peach seedlings 11 weeks after inoculation. Fig. 2) Proportion of fresh root weight of Nemaguard peach seedlings from different positions within growth pouches after 11 weeks.





Figures 3-4. Before planting Nemaguard peach seedlings in pouches, four plants were treated by immersion in a suspension of *Pseudomonas aureofaciens* BG33CL1R (5.3 x 10^8 CFU/ml), and eight plants were treated as controls in sterile distilled water. *Criconemella xenoplax* was applied to all seedlings. At harvest, pouches were cut into 4-cm strips, and nematodes were washed off roots and the paper wick in each strip. Fig. 3) Proportion of *Criconemella xenoplax* population found at different positions within growth pouches after 12 weeks. Fig. 4) Proportion of fresh root weight found at different positions within growth pouches after 12 weeks.

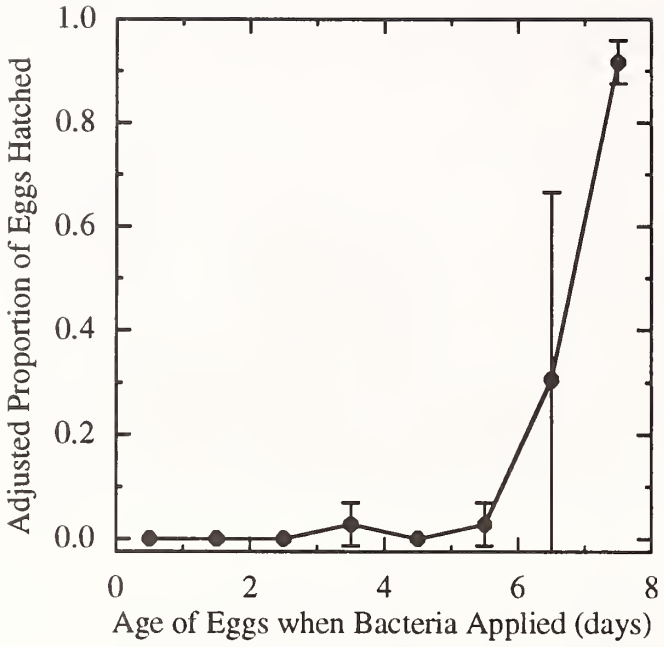


Figure 5. Adjusted proportion of *Criconemella xenoplax* eggs that hatched in treatments of *Pseudomonas aureofaciens* BG33CL1R applied to eggs of different age. The proportion of eggs hatching was adjusted to a fraction of respective water controls. Second stage juveniles were first observed in eggs at 6.5 days in water controls.

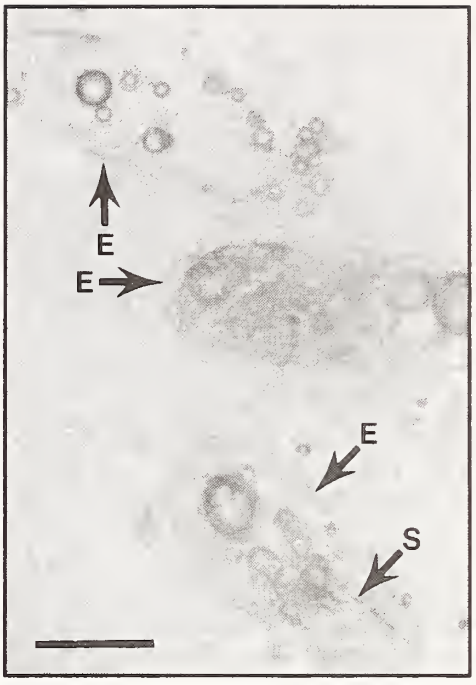


Figure 6. Eight-day-old *Criconemella xenoplax* eggs incubated in water for 5.2 days before addition of *Pseudomonas aureofaciens* BG33CL1R. None of the eggs hatched by the end of the 2-week incubation. Appearance of a stylet indicates that molting to the second-stage juvenile had begun before death for some eggs. E = egg shell; S = stylet; Bar = 100 µm.

PARASITIC AND NONPARASITIC DISORDERS AFFECTING SWEET CHERRY TREES IN MICHIGAN[1]

H. Melakeberhan[2], A.L. Jones[3] and G.W. Bird[2]

ABSTRACT

A detailed analyses of parasitic and nonparasitic disorders of five, 6- to 16-yr-old sweet cherry (*Prunus avium*) orchards, with nine cultivars and over 1,200 total trees was conducted in 1990 and 1991. *Pratylenchus penetrans, Criconemella xenoplax* (=*Mesocriconema xenoplax*), and *Xiphinema americanum* were found to be the most common nematodes associated with *Pseudomonas syringae* in the declining sweet cherry orchards. However, there was no difference in nematode population densities between healthy and diseased trees, suggesting that it is unlikely that the nematodes predispose trees to bacterial canker or were causing a decline of the trees. However, their numbers are believed to be high enough to warrant nematode suppression measures. Among the nonparasitic factors were low soil pH, some nutritional deficiencies, and winter injury, all of which, with the exception of low soil pH, varied from orchard to orchard. It appears that the sweet cherry tree decline in Michigan is a function of interaction of the parasitic and nonparasitic factors, with soil pH as the most important factor.

INTRODUCTION

Our overall project goal was to determine the factors, in particular the role of plant-parasitic nematodes and *Pseudomonas syringae*, that result in the decline of sweet cherry (*Prunus avium* L.) trees in Michigan. The significance of the sweet cherry industry in Michigan, and the type and the extent of distribution of plant-parasitic nematodes and their general association with *P. syringae* in Michigan sweet cherry orchards have been reported (Melakeberhan et al., 1990). The primary nematode genera that we found associated with *P. syringae* were *Pratylenchus, Criconemella*, and *Xiphinema*. This study was followed by a detailed analyses of tree health, presence of plant-parasitic nematodes and *P. syringae*, nutrients, soil pH, and winter injury in five selected orchards. An overview of our findings is presented here.

MATERIALS AND METHODS

Orchard background information: The five cherry orchards were located in three counties in the lower peninsula of western Michigan. Orchard 1 was located in Berrien County (southwest), Orchard 2 in Oceana County (west central), and Orchards 3 - 5 within ca. 20 km from each other in Leelanau County (northwest). Orchards 1 - 5 were planted in 1976, 1986, 1979, 1982, and 1983, respectively. Study sites of 128 to 432 trees, including a portion of each orchard with trees in decline, were selected (Table 1). All trees were propagated on mazzard rootstock and the cultivars in these orchards were Bing, Hedelfingen, Van, and Vista (Orchard 1), Gold and Napoleon (Orchard 2), Emperor Francis and Nelson (Orchards 3 and 4), and Sam (Orchard 5). All trees but those in Orchard 1 were trickle irrigated, and the soil texture was sandy in Orchard 2 and sandy loam in the other four orchards. Grower supplied information on the use of nitrogen fertilizer and lime for 1989 to 1991 showed that ammonium

[1]We thank the growers for their collaboration throughout the study and the local Michigan State University Cooperative Extension Service personnel for assistance in locating sweet cherry orchards. The technical assistance by J. Davenport, and soil and nutritional analysis by the Michigan State University Soil Testing and Animal Toxicology Laboratories personnel, and the financial support by USDA agreement 88-34152-3380 and the Michigan Agricultural Experiment Station are greatly appreciated.

[2]Visiting Assistant Professor and Professor, Department of Entomology, Michigan State University, East Lansing, MI 48824

[3]Professor, Department of Botany and Plant Pathology and the Pesticide Research Center, Michigan State University, East Lansing, MI 48824

nitrate was applied at ranges of 259 kg/ha (Orchard 4) to 334 kg/ha (Orchard 2) per year. Orchard 3 was limed in 1989 at a rate of 2,808 kg/ha.

Orchard health assessments: Individual trees within the study sites of each orchard were assessed for symptoms of bacterial canker on lateral and scaffold branches, winter injury, and tree mortality before and after the initiation of the study (1990). Trees were categorized as healthy (no visible cankers), less healthy (cankers on lateral branches) and diseased (cankers on scaffold branches). Trees with depressed areas of necrotic tissue extending upward from the soil line on the south side of the tree were considered winter injured. Trees obviously younger than other trees were classified as replants.

Isolation of *Pseudomonas* bacteria: Cankers with gum extending from the bark were removed from trees in each orchard and transported to the laboratory. The surface of the bark was cleaned by scraping away the gum deposits, and the cankerous tissues were dipped into NaOCl (5.25%) for 30 s. After drying for about 20 min, the bark was pulled back with a sterile knife and 1- to 2-mm-thick segments of the exposed necrotic tissue were placed on King's medium B (King et al., 1954). Fifty leaves per cultivar were randomly collected from each orchard at each sampling date for bacterial isolations (King et al., 1954). The colonies of fluorescent bacteria that developed around the segments were purified before identifications were made as described in detail in Melakeberhan et al. (1992).

Soil and root sampling for nematode analysis: Soil samples were collected at approximately 4-wk intervals in summers and falls of 1990 and 1991. On each sampling date, a total of 32, 36, 36, 48, and 72 samples were collected from trees in Orchards 1 - 5, respectively. Each sample was a composite of four to six cores of soil taken to a depth of 15 - 20 cm with a Hoffer soil sampler between the canopy edge and the trunk from each of four to six trees. On each sampling date, composite samples were also collected from diseased trees in Orchards 1, 3, and 4. At the end of each season, similar soil samples were also collected from healthy trees. A total of 16, 18, 18, 24, and 12 root samples per orchard were collected from healthy and diseased trees in Orchards 1 - 5, respectively, in the falls of 1990 and 1991. Root samples were collected with a small shovel to 15 - 20 cm depth from two random locations around four to six trees per sample. A similar number of root samples was collected from each of the cultivars in each orchard. Nematode extractions, population density estimations and species identifications were as described in Melakeberhan et al. (1992).

Soil and leaf analyses. The levels of pH and N, P, K, Mg, and Ca were determined by the Michigan State University Soil Testing Laboratory from a total of four to six composite soil samples per orchard in June 1991. Available soil Al was determined from four composite soil samples per orchard collected in late August or early September 1991 as described by Barnhisel and Bertsch (1982). The concentrations of N, P, K, Mg, Ca, Fe, Mn, Cu, Zn, B, and Al were determined from a total of 12, 6, 6, 6, and 3 composite leaf samples, three samples per cultivar and per tree health category, collected in late July (Orchards 1 - 2) and early August 1991 (Orchards 3 - 5) (Kenworthy, 1967). Each sample consisted of 40 - 50 leaves per tree from three to four trees (Melakeberhan et al., 1992).

Data analysis: Tree health assessments and isolations for *Pseudomonas* were converted to percentages. Nematode population densities, nutrient data were compared by variety, tree health and orchard, and data were analyzed by one-way ANOVA with unequal number of replications and means separated by Tukey's studentized range test utilizing SAS. Unless differences between and among cultivars were observed, data for each parameter are presented by orchard.

RESULTS AND DISCUSSION

General orchard status: By the end of the 1991 season, Orchards 2, 4 and 5 had ca. 83, 34 and 86% healthy trees, respectively; whereas,

Orchards 1 and 3 had fewer than 10% healthy trees (Table 1). The number of dead and replanted trees accounted for ca. 10 to 31% in Orchards 1 - 3; whereas, it was less than 2% in Orchards 4 and 5 (Table 1). The difference between the healthy and dead or replanted and the total number of trees represent trees with canker symptoms on either lateral or scaffold branches. Winter injury was severe in Orchard 3, minor in Orchard 4, and nonexistent in the other orchards (Table 1). Thus, despite the widespread sweet cherry tree decline in Michigan, the factors responsible appear to vary with location.

Isolation of pathogens: *Pseudomonas* spp. were isolated from 18 to 100% of leaves and cankers collected from each orchard (Fig. 1). The fact that *Pseudomonas* was not isolated from all cankerous tissues may indicate that cankers may be caused by other factors such as winter injury. Nonetheless, the incidence of bacterial canker by itself does not appear to be enough to kill the trees (Melakeberhan et al., 1992).

Soil samples collected from each of the five orchards contained *P. penetrans, C. xenoplax, X. americanum, Meloidogyne hapla, Paratylenchus* spp. and other species. However, the former three and in particular *P. penetrans*, were the most abundant nematodes. Although there were seasonal fluctuations in nematode numbers over the two years of the study, the overall averages per orchard are representative of the variations (Fig. 2). *Pratylenchus penetrans* was by far the most abundant nematode in all orchards; whereas, *C. xenoplax* and *X. americanum* were abundant in the southwest of Michigan (Fig. 2). The numbers of *P. penetrans* were higher compared with other reported populations (Mai and Parker, 1967; Mai and Parker, 1972) which were damaging to young cherry trees, indicating the need of control measures. As with *Pseudomonas*, however, the nematode numbers alone do not appear to be high enough to cause tree decline. Moreover, the fact that the number of nematodes extracted from soils or roots of healthy trees was similar to the numbers from diseased trees for Orchards 1, 3, and 4 (Fig. 3), suggested that nematodes may not be predisposing the trees to bacterial canker. Nonetheless, the ability of the three most important nematodes to cause disease by themselves and by interacting with other pathogens needs to be considered.

Nonparasitic disorders: Most of the orchards had some form of insufficiency in either leaf or nutrient concentrations of the major or minor elements that were determined (Table 2). If continued over long periods of time, nutrient insufficiencies may play some role in the decline of sweet cherry trees. The levels of leaf Al concentrations particularly in Orchard 1 (Table 2) are higher than those reported to be toxic to other *Prunus* spp. (Chibiliti and Byrne, 1989; Edwards and Horton, 1977; Edwards et al., 1976). Considering the level of tree mortality in Orchard 1 and the effect of Al, it is likely that Al may be involved in the decline of the trees in this orchard.

The most common factor in all of the studied orchards was the low soil pH value, which resulted in lime requirements of ca. 2.2 to 4.6 tons/ha (Table 3). The recommended soil pH for Michigan sweet cherry orchards is 6.5. It appears that the low pH was a result of infrequent liming (as the growers records show) as well as the use of ammonium nitrate, (a known factor in decreasing soil pH) in the studied orchards. Moreover, low pH may have affected the availability, uptake and metabolism of nutrient elements (Table 2). Furthermore, low soil pH may have increased the availability and uptake of Al (Foy, 1974), leading to the decline of the trees over time. This indicates that increasing and maintaining soil pH at the recommended level will likely improve tree health.

It generally appears that the parasitic and nonparasitic factors may contribute to sweet cherry tree decline in Michigan. We tried the typical nematodes-bacterial canker interaction experiments, but we were unable to show an increase in the severity of bacterial canker. When the same interaction experiments were repeated under soil pH ranges that were observed in the field, however, we were able to accelerate

the disease symptoms. Therefore it appears that soil pH is a driving factor(s), similar to what has been shown on peach (Weaver and Wehunt, 1975).

LITERATURE CITED

Barnhisel, R. and P.M. Bertsch. 1982. Aluminum, Pp. 275-300. In: A.L. Page (ed.) Methods of Soil Analysis. Amer. Soc. Agron., Madison, WI. 1159 Pp.

Chibiliti, G.B. and D.H. Byrne. 1989. Relative aluminum tolerance of *Prunus* rootstocks. HortScience 24:657-658.

Edwards, J.H. and B.D. Horton. 1977. Aluminum-induced calcium deficiency in peach seedlings. J. Amer. Soc. Hort. Sci. 102:459-461.

Edwards, J.H., B.D. Horton and H.C. Kirkipatrick. 1976. Aluminum toxicity in peach seedlings. J. Amer. Soc. Hort. Sci. 102:139-142.

Foy, C.D. 1974. Effects of aluminum on plant growth, Pp. 601-640. In: E.W. Carson (ed.) The plant root and its environment. Charlotteville, VA. The Univ. Press of Virginia.

Kenworthy, A.L. 1967. Plant analysis and interpretation of analysis for horticultural crops, Pp. 59-92. In: Soil Testing and Plant Analysis. Soil Sci. Soc. Amer. Pub. No. 2. 114 Pp.

King, E.O., M.K. Ward and D.E. Raney. 1954. Two sample media for demonstration of pyocyanin and fluorescin. J. Lab. Clin. Med. 44:301-307.

Mai, W.F. and K.G. Parker. 1967. Root diseases of fruit trees in New York State. I: Populations of *Pratylenchus penetrans* and growth of cherry in response to soil treatment with nematicides. Plant Dis. Rep. 51:398-401.

Mai, W.F. and K.G. Parker. 1972. Root diseases of fruit trees in New York State. IV: Influence of preplant treatment with a nematicide, charcoal from burned brush, and complete mineral nutrition on growth and yield of sour cherry trees and numbers of *Pratylenchus penetrans*. Plant Dis. Rep. 56:141-145.

Melakeberhan, H., G.W. Bird and A.L. Jones. 1990. Distribution of plant parasitic nematodes in sweet cherry orchards with bacterial canker in Michigan. Fifth Stonefruit Decline Workshop. (In press)

Melakeberhan, H., A.L. Jones, P. Sobiczewski, and G.W. Bird. 1993. Factors associated with the decline of sweet cherry trees in Michigan: Nematodes, bacterial canker, nutrition, pH, and winter injury. Plant Dis. 77:266-271.

Weaver, D.J. and E.J. Wehunt. 1975. Effect of soil pH on susceptibility of peach to *Pseudomonas syringae*. Phytopathology 65:984-989.

Table 1. Total number of trees, and percentage of winter injured, dead and replanted, and healthy trees at the end of the 1991 growing season in five Michigan sweet cherry orchards.

Orchard codes	Total trees (#)	Winter injured (%)	Dead and replanted (%)	Healthy (%)
1	128	0.0	30.5	6.3
2	216	0.0	10.1	83.0
3	216	54.2	20.4	5.5
4	288	6.9	1.7	34.4
5	432	0.0	1.4	86.3

Table 2. Mean concentrations of N, and P, K, Mg and Ca in soil (A) and leaves (B), and Fe, Mn, Cu, Zn, B and Al in leaves (C) from five Michigan sweet cherry orchards.

A) Soil samples

Orchard codes	Elemental concentrations[z]				
	NO_3	P	K	Mg	Ca
	(kg/ha)				
1	65.3 b	245.4 b	152.2 c	134.8 ab	539.1 b
2	197.6 a	160.4 c	79.7 d	113.8 b	404.3 b
3	108.2 b	111.6 c	167.5 c	137.7 ab	1594.5 a
4	199.5 a	288.4 ab	220.5 b	175.0 a	1707.0 a
5	199.2 a	328.9 a	475.1 a	145.5 ab	1527.5 a

B) Leaf samples

	N	P	K	Mg	Ca
	(%)				
1	2.13 c	0.17 a	1.60 ab	0.48 ab	1.47 b
2	2.37 bc	0.18 a	1.16 b	0.55 a	1.54 b
3	2.15 bc	0.14 b	1.39 ab	0.35 b	1.57 b
4	2.44 b	0.17 a	1.80 a	0.42 ab	2.30 a
5	2.75 a	0.17 a	1.44 ab	0.33 b	1.62 b

C) Leaf samples

	Fe	Mn	Cu	Zn	B	Al
	(ppm)					
1	170.1 a	109.9 ab	183.3 a	18.4 b	31.9 8b	392.1 a
2	101.7 bc	101.5 ab	5.8 b	14.0 b	38.3 b	87.2 bc
3	113.8 b	48.2 bc	5.0 b	23.8 b	50.8 a	111.5 b
4	107.7 bc	23.7 c	3.2 b	14.3 b	41.5 ab	121.2 b
5	80.0 c	124.0 a	6.3 b	178.7 a	38.3 b	44.0 c

[z]Means followed by the same letters are not significantly different from each other.

Table 3. Soil pH, and lime, P and K amendment requirements in five Michigan sweet cherry orchards.

Orchard codes	Amendments Required[z]			
	pH	Lime	P	K
	(kg/ha)[y]			
1	4.83 b	3482	0.0 b	129.2 b
2	4.35 b	4414	0.0 b	202.2 a
3	5.44 a	4616	12.8 a	115.6 b
4	5.43 a	3842	0.0 b	59.9 c
5	5.68 a	2246	0.0 b	0.09 d

[z]Based on MSU plant tissue and soil analysis and extension recommendations.
[y]Numbers followed by the same letters are not significantly different from each other at P = 0.05.

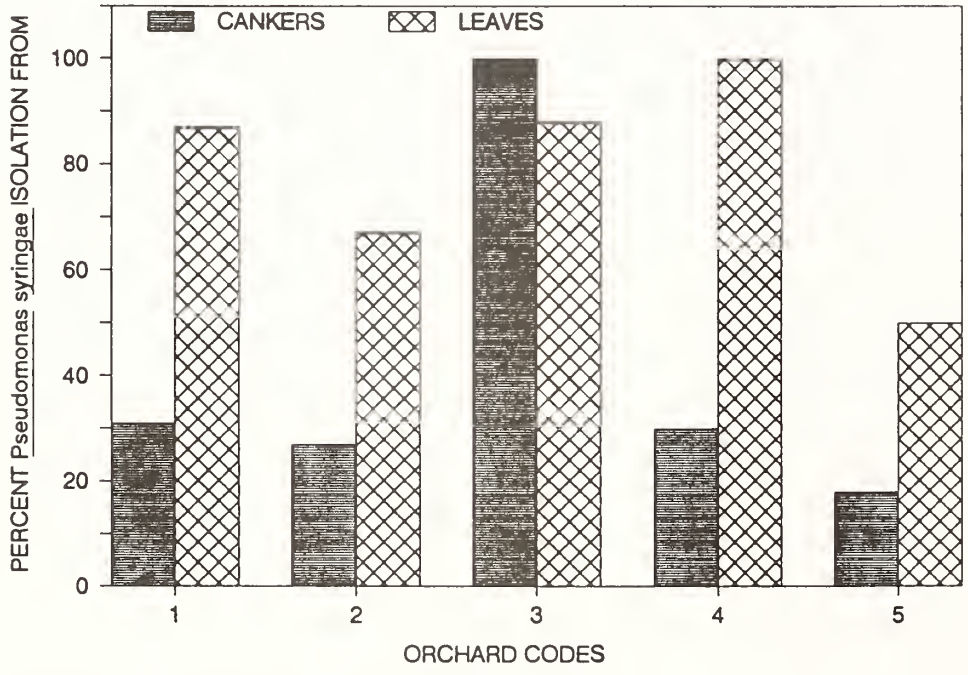


Figure 1. The percentage of cankers and leaf samples from which *Pseudomonas syringae* were isolated in five Michigan sweet cherry orchards.

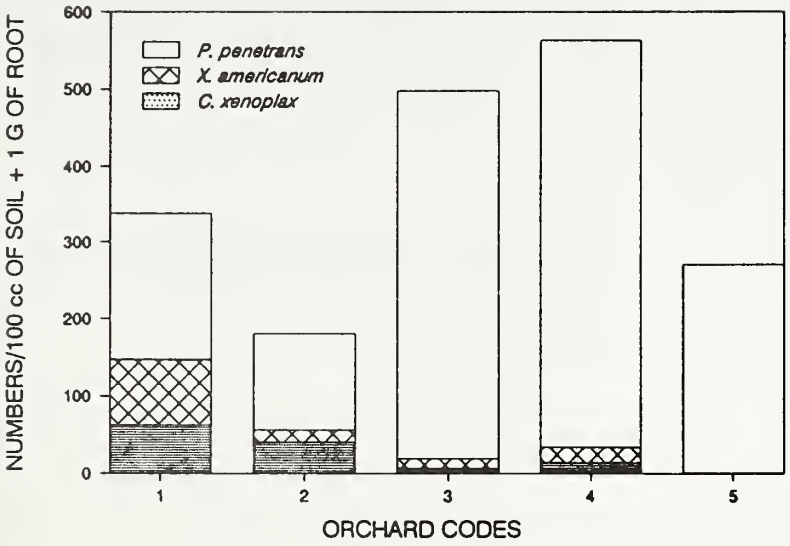


Figure 2. Mean population densities of *Pratylenchus penetrans, Criconemella xenoplax*, and *Xiphinema americanum* recovered from 100 cm^3 of soil and 1 g of root samples from all tree health categories in five sweet cherry orchards taken in 1990 and 1991 under all trees in five Michigan sweet cherry orchards.

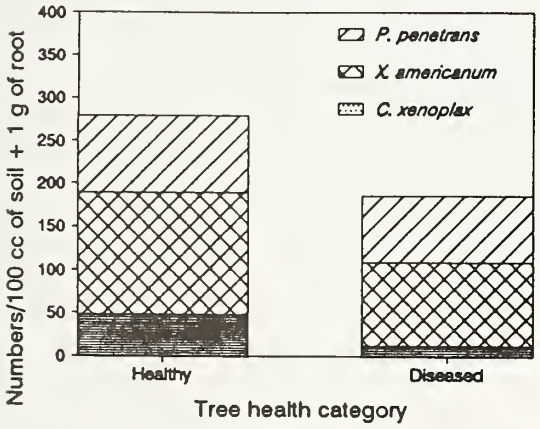


Figure 3. Mean population densities of *Pratylenchus penetrans, Criconemella xenoplax*, and *Xiphinema americanum* recovered from 100 cm^3 of soil and 1 g of root samples taken in 1990 and 1991 under healthy and diseased trees in three (1, 3, and 4) Michigan sweet cherry orchards.

A COMPUTER PROGRAM TO ASSIST NEMATODE MANAGEMENT IN GEORGIA PEACH ORCHARDS

P.F. Bertrand[1] and B.G. Taylor[2]

A computer program entitled PEACH NEMATODES was developed to compile and organize the nematode control recommendations used for peaches in the state of Georgia. It is also designed as a tool to assist county agents to train themselves and their clientele in dealing with various nematode situations that may arise in commercial peach production. The PEACH NEMATODES software package requires an IBM PC or compatible computer with a minimum of 256 KB RAM, one 5 1/4 inch disk drive or hard disk and DOS 2.0 or higher.

INPUTS

The following information is needed to operate PEACH NEMATODES. The various inputs are requested at various places in the stepwise operation of the program (Fig. 2-21).

A. Grower name and address
B. Grower sample number
C. Date of report
D. Site
    1) Future orchard OR
    2) Established orchard
E. Present Crop
F. Previous Crop
G. Month Samples Collected
H. County Where Samples Collected
I. If Samples are from a Future Orchard Site:
    1) Has the site been in orchards before
    2) Years since the previous orchard was removed
    3) Does the site have a history of peach tree short life (PTSL)
    4) Does the site have a history of root-knot nematode problems in any crop
J. If samples are from an established orchard:
    1) Orchard age
    2) Rootstock
    3) Is the orchard:
        a) Healthy
        b) Declining
        c) Dying
        d) Other symptoms
K. Results of a soil test for nematodes

All inputs except county name can be invented to create any hypothetical situation that may be desired. County name must be one of the 159 Georgia counties. The site must be either a future site or an established orchard. An orchard scheduled for removal and replacement should be viewed as a future orchard site. In preparing this program, various assumptions had to be made. In all cases, we took a conservative approach. Changing various inputs can directly influence the response generated.

The month of sampling becomes very important when harmful nematodes are not found. In this program the best time to sample for the ring nematode (*Criconemella xenoplax* = *Mesocriconema xenoplax*) is assumed to be February-April with other times, for various reasons, considered not as good. In the case of lesion and root-knot nematode, August-October is assumed to be the best sample time. References to these sampling windows will be made when harmful nematodes are not found.

The county where samples are collected will affect recommendations generated by the program. The state of Georgia is divided along county lines into three zones: North, Central and South (Fig. 1). The divisions, in part arbitrary, represent an attempt to rate the value of Nemaguard rootstock in different regions of Georgia in terms of probability of long term survival:

North - Nemaguard rootstock not recommended
Central - Nemaguard rootstock recommended with caution
South - Nemaguard rootstock recommended

---

[1] Professor of Plant Pathology, The University of Georgia Cooperative Extension Service, P.O. Box 1209, Tifton, GA 31793

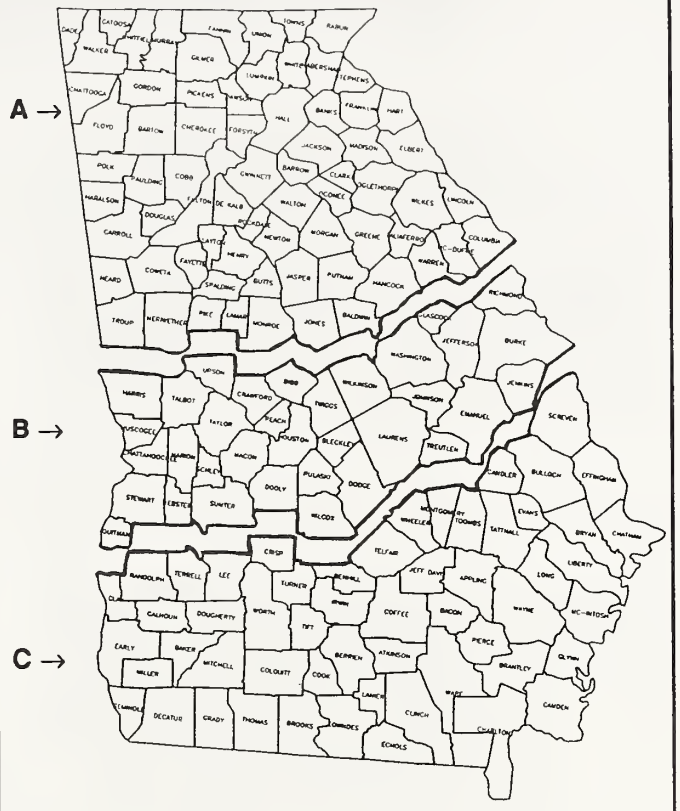
[2] Computer Services Programmer, Specialist III, The University of Georgia, Cooperative Extension Service, P.O. Box 1209, Tifton, GA 31793

In Central or South Georgia recommendation of Nemaguard is only made when *C. xenoplax* or any history of *C. xenoplax* related problems is absent.

The regions are also used to estimate the date by which fall fumigation should be completed before soil temperature becomes to cold for best results. Long term soil temperature data was available for Athens (North), Byron (Central), and Tifton (South). The optimum soil temperature for soil fumigation is 15-25 C. Using soil temperature records for each site we calculated an average date when soil temperature dropped below 15 C. This date was shifted approximately 2 weeks earlier to derive the following target dates for completion of fall fumigation.

North - 15 October
Central - 1 November
South - 15 November

In designing this program, we assumed that *C. xenoplax, Pratylenchus vulnus* and all *Meloidogyne* species are the only nematodes found in Georgia that are harmful to peaches. This assumption is supported by survey results. There is a built in caution regarding the susceptibility of Nemaguard rootstock to peanut root-knot nematode (*Meloidogyne arenaria*) for samples collected in the southwest Georgia peanut belt. We also assumed any detectable level of these nematodes or history of problems associated with these nematodes constitutes a potential problem. Nematode populations are treated in different ways depending on whether the site is a future orchard or a bearing orchard (See Appendices 1-6).



NORTH GEORGIA (A)

1. Plan to complete preplant fumigation by 15 October.

2. Do not use Nemaguard rootstock. This risk of cold damage is too great.

CENTRAL GEORGIA (B)

1. Plan to complete preplant fumigation by 1 November.

2. Nemaguard rootstock can be used with some risk of cold injury on sites free if *C. xenoplax* and not previously planted to peach.

SOUTH GEORGIA (C)

1. Plan to complete preplant fumigation by 15 November.

2. Nemaguard rootstock can be used on sites free of *C. xenoplax* and not previously planted to peach.

Figure 1. The geographic division of Georgia used in PEACH NEMATODES.

Figures 2-21 provide a step by step illustration as to how the program is operated. Samples of the reports generated with this program are shown in Appendices 1-6. The text of these reports is influenced by county location, month of sampling and orchard health and age (in the case of established plantings).

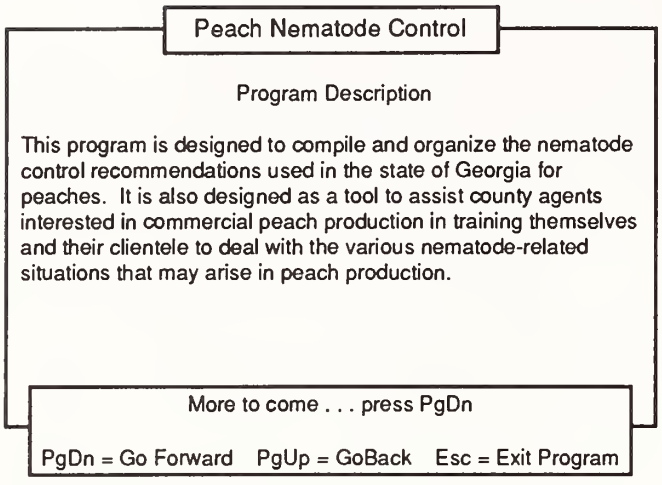


Figure 2. Following a UGA title screen, this screen will appear. Pressing the <PgDn> key will usually continue operation of the program to the next step. However several screens where input required to operate the program is requested cannot be bypassed with the <PgDn> key. Filling in the information is required to advance the program. As the last required item is entered, the program will move forward automatically. Pressing the <PgUp> key will take the operator back to the previous step. Pressing the <Esc> key will exit the program at any time. These are the basic directions used in working back and forth through this program.

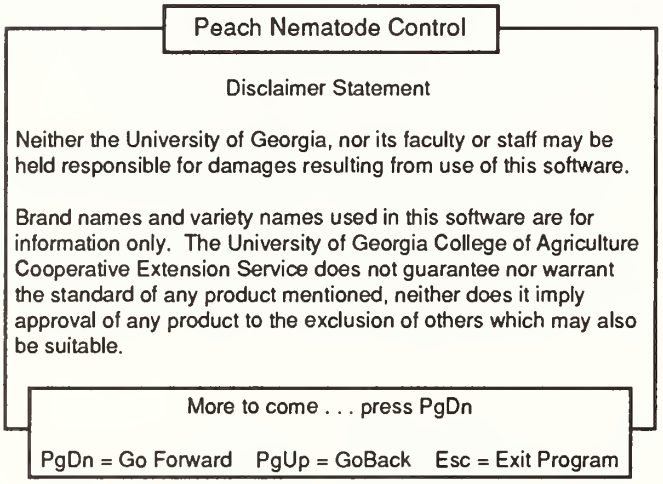


Figure 3. Standard UGA software disclaimer. A computer is merely a high speed data retrieval and processing tool. The operator is expected to understand the inputs and their accuracy. If inaccurate information is put in, an inaccurate site assessment will come out. The computer assumes that all inputs are precisely accurate.

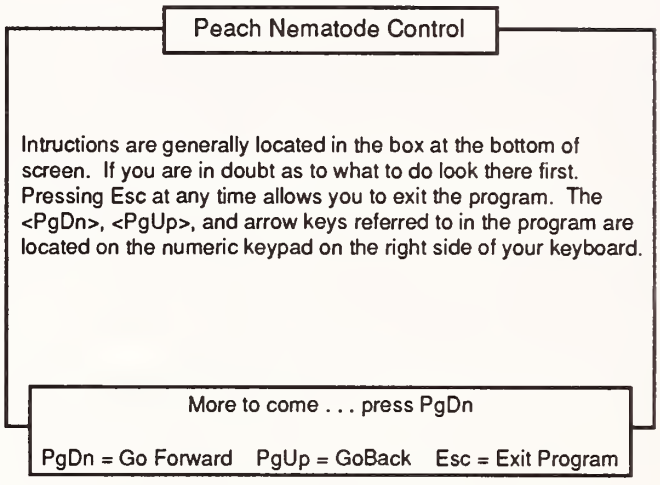


Figure 4. General operating instructions, as noted previously.

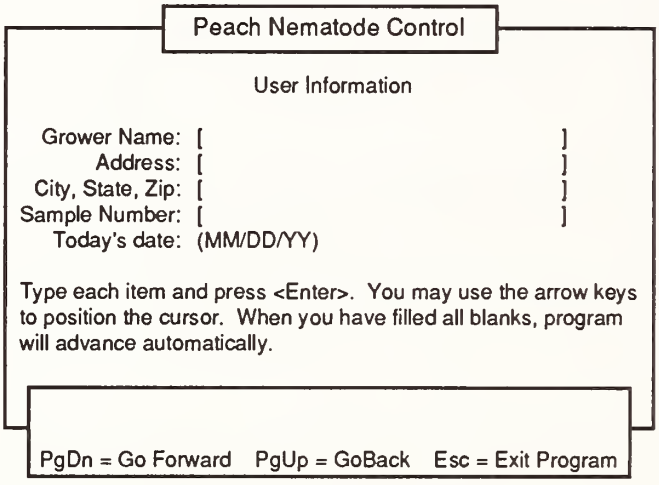


Figure 5. This is the first of series of steps where data collected and knowledge of a specific site is entered into the program. The computer will use this data to prepare an evaluation of the site in question. The data requested here is not necessary to operate the program, but is necessary to keep track of the printed reports that can be generated.

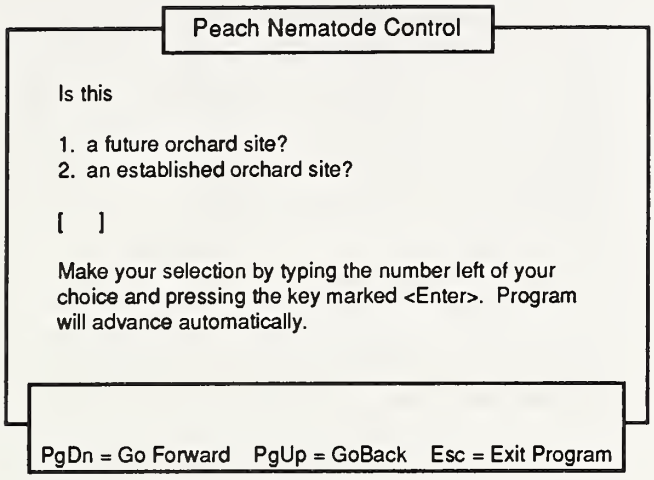


Figure 6. This question must be answered to operate the program. If option #1, a future orchard site is chosen, proceed to Figure 7. If option #2, an established orchard site is chosen, proceed to Figure 18.

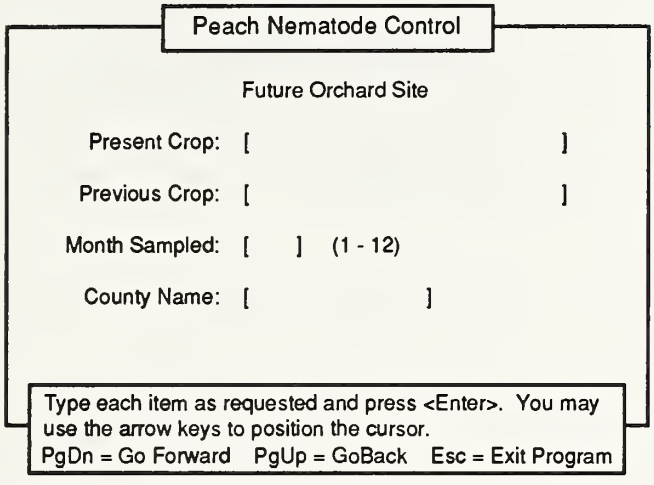


Figure 7. If option #1, a future orchard site, has been selected, the following input requests will appear. Present crop is currently only important if it is peanut. Previous crop is currently important if it is either peach or peanut. However, knowledge of the present or previous crop may provide information beyond the standard recommendation such as providing a clue to species of root-knot nematodes if such are found.

There are currently several research projects in Georgia and South Carolina on identification and development of rotational crops that are immune to the nematodes that attack peach. The goal is to develop rotations that can be used to control nematodes in peach. As this work develops, knowledge of present and previous crops will become more important.

MONTH SAMPLED: It is critical that the month the samples were collected be known and entered. Leaving all other data constant and changing the month sampled will frequently result in generation of very different reports by the program.

COUNTY NAME: The state of Georgia has been divided into three zones based on the risk of using Nemaguard rootstock and the average last date recommended for completion of preplant fumigation. Enter the name of the county where the samples were collected to place the site in its proper zone.

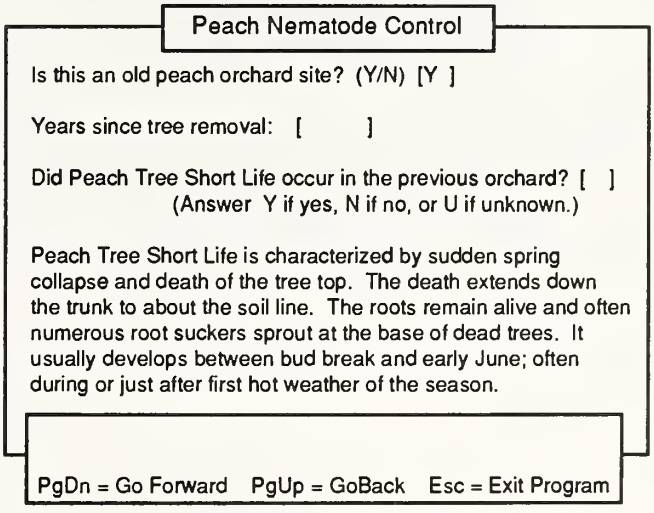


Figure 8. If the answer to the first question on the screen is Yes (Y), the next question will appear automatically. When it is answered the third question appears automatically. If the answer to the first question is NO (N), the other questions do not appear.

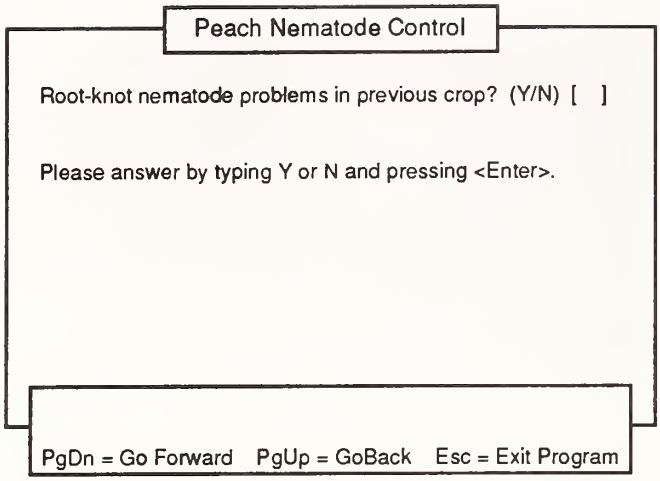


Figure 9. The answer to this question is very important. Detailed knowledge of crop history and nematode related troubles on a piece of land is as useful as the numbers of nematodes found. If the answer to the question above is YES (Y), it is then assumed that root-knot nematodes are present even if they were not found in the sample. The report generated by this program would then address control of root-knot nematode.

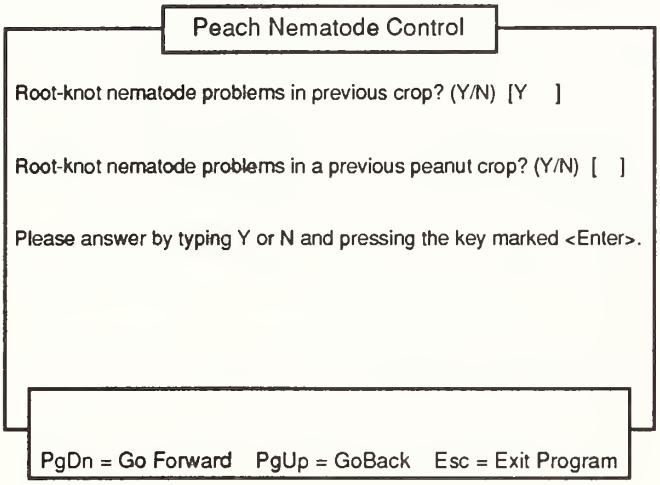


Figure 10. If the answer to the first question is YES (Y) and the present or previous crop is peanut or the sample was taken in a county where peanut root-knot nematode commonly occurs, the second question will appear. The answer is important because Nemaguard rootstock is NOT resistant to peanut root-knot nematode.

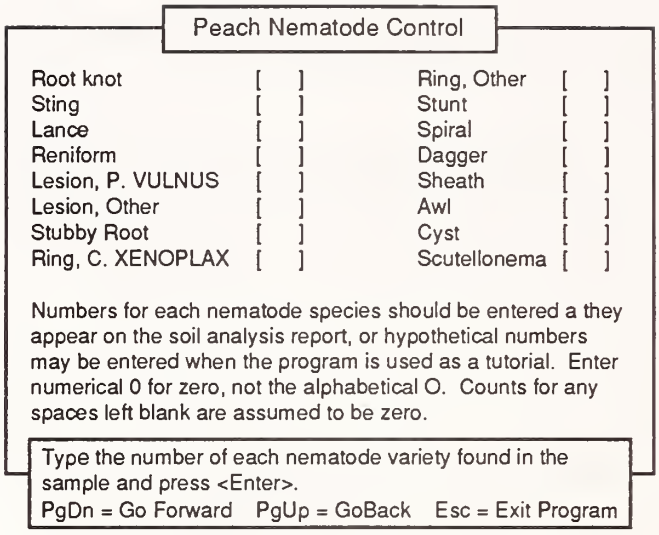


Figure 11. The counts of each nematode found in the soil sample are entered in the appropriate space. The only species of root-lesion nematode that is harmful to peach and found in Georgia is *Pratylenchus vulnus*. It must be determined if this species is present for the assay to have any value. The only species of ring nematode harmful to peach that is found in Georgia is *C. xenoplax*. It must be determined if this species is present for the assay to have any value. When the last numbers are entered, press <PgDn> to generate site evaluation and recommendations.

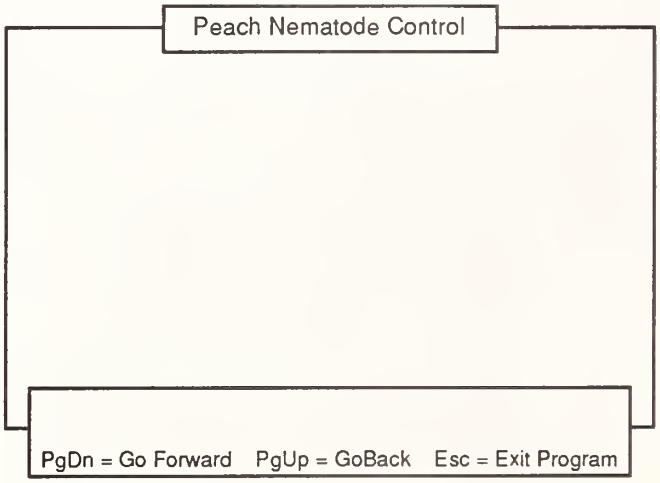


Figure 12. Based on all the various inputs, a report on the situation along with an appropriate recommendation will appear on this and the next one or more screens.

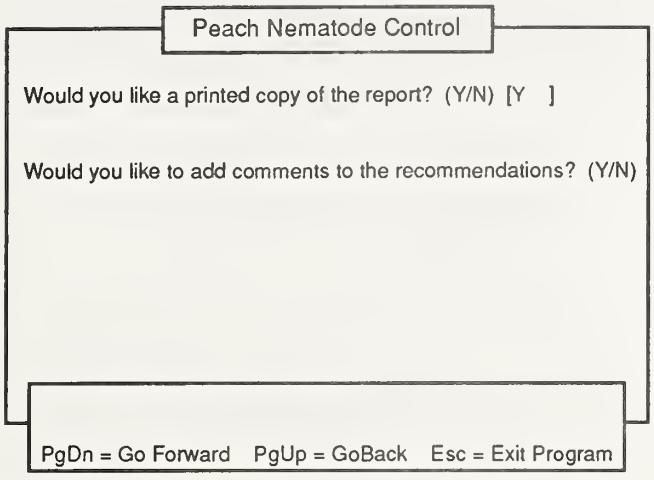


Figure 13. When the report and recommendation are complete, this screen will appear. If you are creating hypothetical situations and want to backtrack to change one or more items to see the effect on recommendations, DO NOT answer this question, merely back up to the desired screen with <PgUp>.

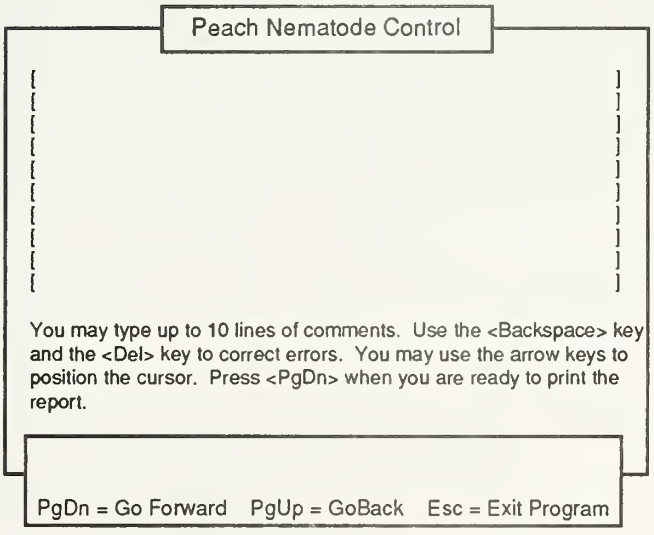


Figure 14. These lines were generated by answering YES to the previous question. Use this space to make any comments necessary to make the recommendation generated by the program more relevant to the specific site in question.

If the answer to the first question is NO (N), the program stops and returns to the beginning. If the answer to the first question is YES (Y), the second question appears automatically. If the recommendation seems to fit all that is known about the situation and all of the inputs are correct, then answer NO (N). If there is something known about the situation that requires modification of the recommendation or an additional comment or reminder, than answer YES (Y). If the answer is YES, you will be given 10 lines in which to make any comment (Figure 14).

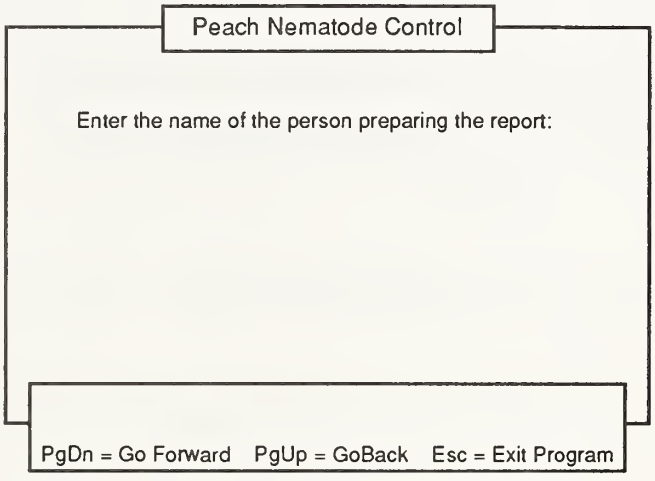


Figure 15. At the end of the report, a signature line is provided for the County Agent, Extension Specialist or Crop Consultant making the report.

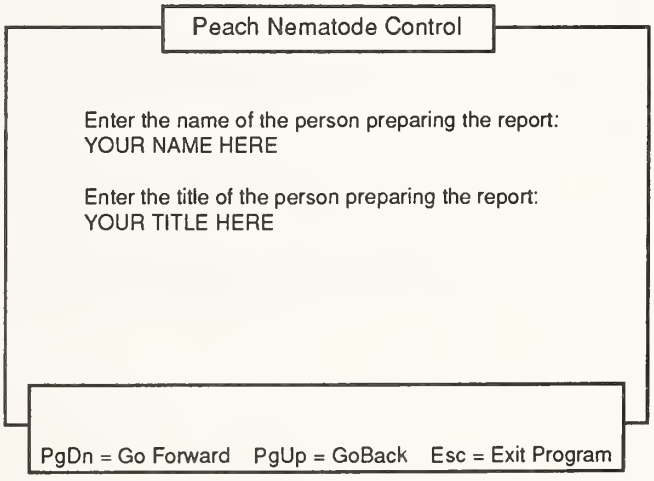


Figure 16. When the name of the person making the report is typed and <Enter> is pressed, a space for the person's title will appear. Type in the appropriate title and press <Enter>.

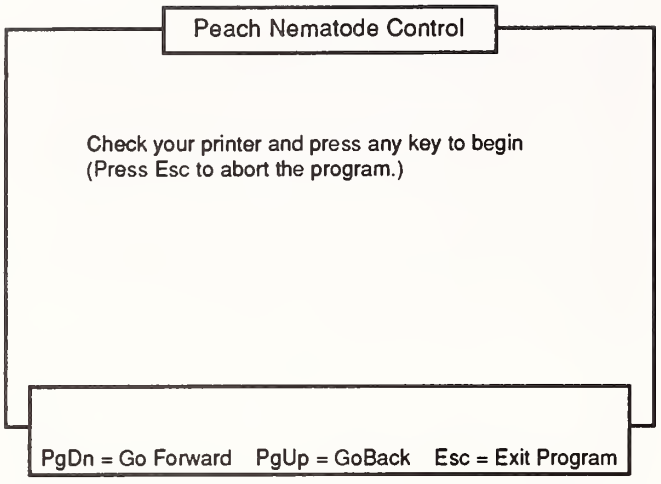


Figure 17. At the completion of the report, press any key (except <Esc>) to get a printed copy of the report.

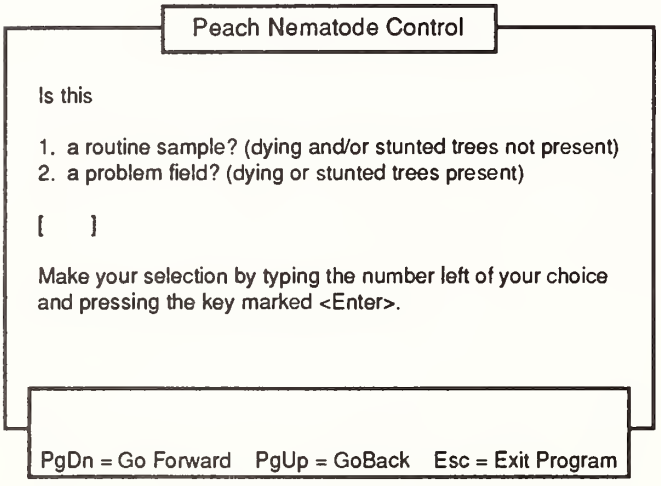


Figure 18. If option #2, an established orchard, has been selected, the following input request will appear. The correct answer to this question is necessary to get a proper recommendation for the orchard in question. Choose option #1 if the orchard is in good health. Choose option #2 if the orchard or some portions of the orchard are not in good health.

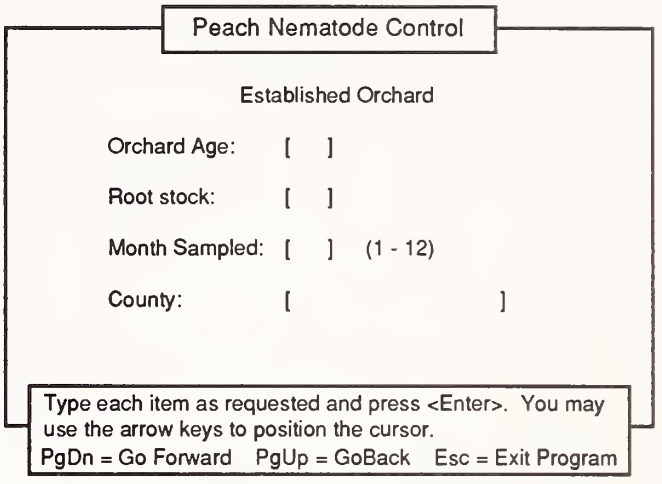


Figure 19. Answer these questions and continue. The recommendations given will, in some cases, be affected by the information given here.

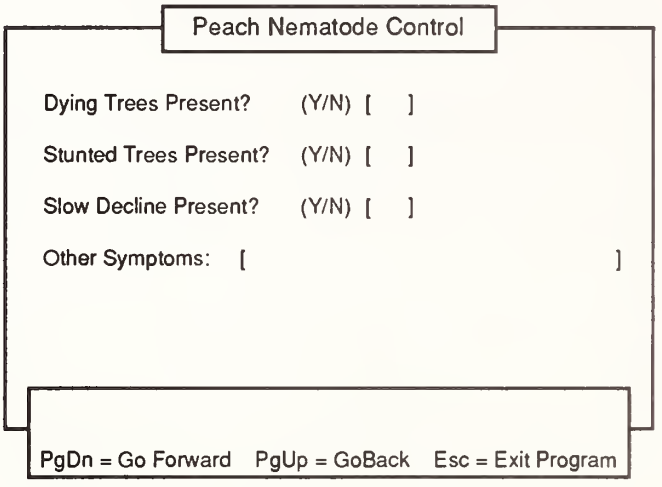


Figure 20. If the orchard is a problem field, this additional information will be requested. Answers to these questions are useful in diagnosis of orchard troubles even if nematodes do not appear to be part of the problem. These answers will be assumed to be NO (N) unless YES (Y) is entered. AT LEAST ONE QUESTION MUST BE ANSWERED WITH A (Y) FOR THIS TO BE A PROBLEM FIELD. Other symptoms can be typed in.

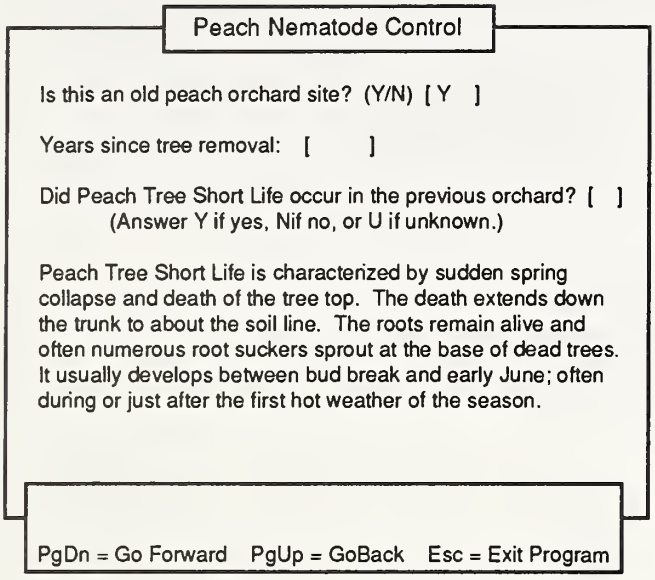


Figure 21. If the answer to the first question shown here is YES (Y), the next question will appear automatically. When it is answered the third question appears automatically. If the answer to the first question is NO (N), the other questions will not appear. From this point, the order of screens appears as illustrated in Figures 11-17.

APPENDIX 1

PEACH NEMATODE CONTROL

Future Orchard Site — Report Date: MM/DD/YY

Data Entered

GROWER NAME
ADDRESS
CITY, STATE, ZIP

County: BROOKS
Month Sampled: AUGUST
Present Crop: FALLOW
Previous Crop: COTTON

Sample number: 1
Old orchard site: No
Root-knot nematode problems in previous crops: No

Nematodes found in sample:

Root-knot:	45	Ring, Other:	432
Sting:	567	Stunt:	0
Lance:	0	Spiral:	0
Reniform:	0	Dagger:	0
Lesion, P. VULNUS	0	Sheath:	0
Lesion, Other:	789	Awl:	0
Stubby Root:	0	Cyst:	0
Ring, C. XENOPLAX:	0	Scutellonema:	0

Recommendations:

Root-knot was the only damaging nematode found. Root-knot nematode can cause severe problems with tree establishment.

Control Options:

A) Use trees on Nemaguard rootstock.
OR
B) Use trees on Lovell rootstock in conjunction with preplant fumigation. To exercise this option, land preparation and fumigation must be finished by November 15.
OR
C) Select another site.

Name
Title

APPENDIX 2

PEACH NEMATODE CONTROL

Future Orchard Site — Report Date: MM/DD/YY

Data Entered

GROWER NAME
ADDRESS
CITY, STATE, ZIP

County: BROOKS
Month Sampled: AUGUST
Present Crop: COTTON
Previous Crop: COTTON

Sample number: 2
Old orchard site: No
Root-knot nematode problems in previous crops: Yes

Nematodes found in sample:

Root-knot:	0	Ring, Other:	0
Sting:	567	Stunt:	890
Lance:	0	Spiral:	0
Reniform:	0	Dagger:	0
Lesion, P. VULNUS	0	Sheath:	0
Lesion, Other:	0	Awl:	0
Stubby Root:	65	Cyst:	0
Ring, C. XENOPLAX:	0	Scutellonema:	0

Recommendations:

Root-knot nematodes were not found, but the land has a history of root-knot problems. It must be assumed that they are present, but missed in sampling.

Root-knot nematodes can cause severe problems with tree establishment.

Control Options:

A) Use trees on Nemaguard rootstock.
OR
B) Use trees on Lovell rootstock in conjunction with preplant fumigation. To exercise this option, land preparation and fumigation must be finished by November 15.
OR
C) Select another site.

Comments:

SOME CAUTION MUST BE OBSERVED WITH POSSIBLE CARRYOVER OF HERBICIDES USED ON PREVIOUS COTTON CROPS.

Name
Title

APPENDIX 3

PEACH NEMATODE CONTROL

Future Orchard Site — Report Date: MM/DD/YY

Data Entered

GROWER NAME
ADDRESS
CITY, STATE, ZIP

County: PEACH
Month Sampled: AUGUST
Present Crop: SOYBEAN
Previous Crop: SOYBEAN

Sample number: 3
Old orchard site: Yes
Years since tree removal: 5
Root-knot nematode problems in previous crops: No

Nematodes found in sample:

Root-knot:	0	Ring, Other:	567
Sting:	0	Stunt:	0
Lance:	65	Spiral:	0
Reniform:	0	Dagger:	0
Lesion, P. VULNUS	0	Sheath:	0
Lesion, Other:	0	Awl:	0
Stubby Root:	0	Cyst:	0
Ring, C. XENOPLAX:	0	Scutellonema:	0

Recommendations:

No nematodes harmful to peaches were found in this assay. However, this is an old orchard site and a poor time to sample for the ring nematode CRICONEMELLA XENOPLAX.

As the previous orchard on this site experienced peach tree short life, it would be a gamble to use this site without fumigation.

Control Options:

A) Select another site not previously in peaches or that is free of harmful nematodes.
OR
B) Prepare land and fumigate this site. Plan to complete fumigation by November 1.
OR
C) Delay planting this site until a February-April nematode sample can be taken to determine if CRICONEMELLA XENOPLAX is present.
AND
D) Do not use Nemaguard rootstock on this site.

Name
Title

APPENDIX 4

PEACH NEMATODE CONTROL

Future Orchard Site — Report Date: MM/DD/YY

Data Entered

GROWER NAME
ADDRESS
CITY, STATE, ZIP

County: PEACH
Month Sampled: MARCH
Present Crop: FALLOW
Previous Crop: SOYBEAN

Sample number: 4
Old orchard site: No

Root-knot nematode problems in previous crops: No

Nematodes found in sample:

Root-knot:	0	Ring, Other:	564
Sting:	0	Stunt:	0
Lance:	34	Spiral:	0
Reniform:	0	Dagger:	0
Lesion, P. VULNUS	0	Sheath:	0
Lesion, Other:	0	Awl:	0
Stubby Root:	543	Cyst:	0
Ring, C. XENOPLAX:	43	Scutellonema:	0

Recommendations:

The ring nematode, CRICONEMELLA XENOPLAX, is a major contributing factor in peach tree short life.

Control Options:

A) Select another site.
OR
B) Prepare land and fumigate this site by November 1.
AND
C) Do not use Nemaguard rootstock on this site.

Name
Title

APPENDIX 5

PEACH NEMATODE CONTROL

Established Orchard Site | Report Date: MM/DD/YY

Data Entered

GROWER NAME
ADDRESS
CITY, STATE, ZIP

County: PEACH
Month Sampled: MARCH
Rootstock: LOVELL
Orchard Age: 3

Sample number: 5
Old orchard site: No

Nematodes found in sample:

Root-knot:	0	Ring, Other:	0
Sting:	67	Stunt:	0
Lance:	0	Spiral:	0
Reniform:	0	Dagger:	0
Lesion, P. VULNUS	0	Sheath:	0
Lesion, Other:	78	Awl:	0
Stubby Root:	0	Cyst:	0
Ring, C. XENOPLAX:	56	Scutellonema:	0

Recommendations:

The ring nematode, **CRICONEMELLA XENOPLAX**, is a major contributing factor in peach tree short life.

Control Options:

A) Establish an annual nematode sampling program with spring (February-April) and fall (September-November) samples each year.
AND
B) Apply Nemacur until 2 years before orchard removal or until dead or missing trees exceed 10%.
AND
C) Do not prune this orchard between October and February.

Name
Title

APPENDIX 6

PEACH NEMATODE CONTROL

Established Orchard Site | Report Date: MM/DD/YY

Data Entered

GROWER NAME
ADDRESS
CITY, STATE, ZIP

County: PEACH
Month Sampled: MARCH
Rootstock: LOVELL
Orchard Age: 9

Sample number: 6
Old orchard site: No

Nematodes found in sample:

Root-knot:	0	Ring, Other:	0
Sting:	876	Stunt:	0
Lance:	0	Spiral:	0
Reniform:	0	Dagger:	0
Lesion, P. VULNUS	78	Sheath:	0
Lesion, Other:	78	Awl:	0
Stubby Root:	0	Cyst:	0
Ring, C. XENOPLAX:	87	Scutellonema:	0

Recommendations:

The ring nematode, CRICONEMELLA XENOPLAX, is a major contributing factor in peach tree short life.

The root lesion nematode, PRATYLENCHUS VULNUS can cause severe tree decline.

Control Options:

A) Establish an annual nematode sampling program with spring (February-April) and fall (September-November) samples each year.

AND

B) Continue an ongoing Nemacur program until 2 years before orchard removal or until dead or missing trees exceed 10%.

BUT

C) Do not begin a new Nemacur program

AND

D) Do not prune this orchard between October and Febuary.

_____
Name
Title

NEMATODE DAMAGE ESTIMATES FOR PEACH

P.F. Bertrand[1]

Very few surveys of nematodes in peach or similar crops have been published (Barker and Clayton, 1973; McKenry and Kretsch, 1987; Nyczepir et al., 1985). Between 1990 and 1992 several states were surveyed as to nematode damage in peach orchards. The survey also attempted to determine how nematicide treatments were scheduled and the percentage of orchards receiving treatment. Six states supplied information for this survey (Table 1).

Nematode losses in perennial crops such as peach are very difficult to estimate. Nematode damage is variable in nature (Bertrand and Nyczepir, 1989; McKenry, 1989) and not always direct, as in the case of the dagger nematode (*Xiphinema americanum* senu lato)/tomato ringspot virus complex (Ogawa and English, 1991). In itself *X. americanum* is not especially damaging to peach trees. However, if the *X. americanum* population is carrying tomato ring spot virus an orchard can be destroyed by stem pitting disease. To further complicate nematode loss estimates the direct and indirect damage is cumulative and often accumulates gradually. Tree loss in the case of the peach tree short life/bacterial canker/ring nematode complex occurs in cycles with major losses occurring some years and little or no loss other years. As tree loss mounts, the value of the affected orchard will depend upon the pattern of loss (random vs. concentrated), annual yield per acre, how the crop is utilized (local sales vs. pack/ship vs. process) and proximity of the orchard to equipment headquarters and packing facilities. Orchard removal decisions require full economic analysis (Baur et al., 1980).

The peach acreage, percent of acreage infested with various damaging nematodes and the estimated percent annual production loss due to nematodes is given in Table 2. As expected, the loss estimates vary from state to state. Nematode loss in Georgia is on the whole very low. Most Georgia peach growers when planning a new orchard seek to acquire by lease a site with no previous history of peach culture. These sites are planted without further regard to potential nematode problems. On the whole, the system works fairly well. When losses do become apparent, they are often very severe but involve only a very small acreage in terms of the statewide total. South Carolina losses are chiefly due to the peach tree short life complex which is closely associated with *Criconemella xenoplax* (=*Mesocriconema xenoplax*) (Nyczepir et al., 1985; Nyczepir et al., 1983). Pennsylvania losses are attributed to stem pitting virus. *Criconemella xenoplax* and root-knot nematodes are not commonly found in samples, and the problems ordinarily associated with these nematodes are not often seen in Pennsylvania. Loss estimates for New Jersey, Michigan and California attempt to include the various losses from several plant-parasitic nematodes and associated tree health problems.

The percentage of orchards receiving nematicide treatment varies greatly from state to state (Table 3). The methods used to determine the need for treatment are basically the same in all states surveyed (Table 3). There are no population thresholds based on cause and effect research used to drive nematicide recommendations. Population thresholds derived from literature, research and observations are used as a basis for pre- and postplant nematicide treatment in Michigan orchards (Table 4). The basic preplant recommendation in other states is to treat, if **ANY** harmful nematodes are found in soil assays. However, the frequency of growers using soil assays is highly variable (Table 3). Comments from South Carolina and New Jersey suggest a reason. In South Carolina only 10-20% of new orchard sites are soil sampled for nematodes.

Through the 1970's and into the 1980's, Clemson University offered a peach orchard management program. Nematode sampling was part of the program and during this period >80% of new orchards were sampled for nematodes prior to

---

[1]Professor of Plant Pathology, University of Georgia Cooperative Extension Service, P.O. Box 1209, Tifton, GA 31793

planting. In New Jersey, the situation is reversed. Prior to recent introduction of an orchard management program, New Jersey peach growers seldom took preplant nematode samples. Now under the program, 60-70% of new orchards are sampled prior to planting. It would seem that nematode samples will be taken, if someone other than the growers take them. In all states crop history, soil texture and local experience are the primary forces that determine whether or not orchard sites receive preplant nematicide treatment.

The use of postplant nematicide is also variable among states (Table 3). Treatment thresholds of 40-50 *C. xenoplax* per 100 cm^3 soil have been used in South Carolina, New Jersey and California. These thresholds are based on correlative observations between *C. xenoplax* populations and orchard health. Experiences in South Carolina indicated this was a very useful treatment threshold for postplant treatment with DBCP which is no longer available. Recent South Carolina experience suggests populations reaching 50 *C. xenoplax* per 100 cm^3 soil may be too high for effective control with fenamiphos and therefore the value of this threshold level is now in question. Orchard age, health and past experience are also used to make decisions on postplant nematicide treatment. In Pennsylvania, the value of postplant nematicides in dealing with the dagger nematode/stem pitting virus complex is being questioned. As previously noted, population thresholds for several species are used as a basis for postplant nematicide treatment in Michigan (Table 4).

Extrapolation of treatment thresholds developed for a particular region or situation to other regions or situations may be risky. As previously noted, the South Carolina threshold for *C. xenoplax* used for DBCP treatment does not seem to be very useful in scheduling fenamiphos treatments. Thresholds derived in cooler regions such as Michigan may be too high for warmer regions, such as California or the deep South, simply due to the effects of soil temperature on nematode activity.

Most states reported their figures to be estimates and no state had absolute confidence in the estimates. Lack of data, resources to gather data and the almost abstract nature of the question are the major difficulties in obtaining more definite numbers.

LITERATURE CITED

Barker, K.R. and C.N. Clayton. 1973. Nematodes attacking cultivars of peach in North Carolina. J. Nematol. 5:265-271.

Baur, L.L., P.J. Rathwell and G.A. King, Jr. 1980. Replacement Decisions in Peach Orchards. SC Expt. Sta. Bul. 627. Clemson Univ., Clemson, SC.

Bertrand, P.F. and A.P. Nyczepir. 1989. Nematodes. In: S.C. Myers (ed.) Peach Production Hdbk. The Univ. of GA, Coop. Ext. Serv., G.E.S. Hdbk. No. 1. 222 Pp.

McKenry, M.V. 1989. Nematodes. In: J.H. LaRue and R.S. Johnson (eds.) Peaches, Plums and Nectarines: Growing and Handling for Fresh Market. Univ. of CA Coop. Ext. Serv. Pub. 3331. 246 Pp.

McKenry, M.V. and J. Kretsch. 1987. Survey of nematodes associated with almond production in California. Plant Dis. 71:71-73.

Nyczepir, A.P., P.F. Bertrand, R.W. Miller and R.E. Motsinger. 1985. Incidence of *Criconemella* spp. and peach orchard histories in short-life and non-short-life sites in Georgia and South Carolina. Plant Dis. 69:874-877.

Nyczepir, A.P., E.I. Zehr, S.A. Lewis and D.C. Harshman. 1983. Short-life of peach trees induced by *Criconemella xenoplax*. Plant Dis. 67:507-508.

Ogawa, J.M. and H. English. 1991. Disease of Temperate Zone Tree Fruit and Nut Crops. Univ. of CA Pub. 3345. 461 Pp.

Table 1. States and contact persons responding to the peach nematode survey.

State	Contact Person(s)
Georgia	P.F. Bertrand and A.P. Nyczepir
South Carolina	R.W. Miller and E.I. Zehr
Pennsylvania	J.M. Halbrendt
New Jersey	J.K. Springer
Michigan	G.W. Bird and H. Melakeberhan
California	M.V.McKenry

Table 2. Peach acreage, percent of acreage infested with various damaging nematodes, and an estimated percent annual production loss due to nematodes.

	States and their peach acreage in survey[z]					
	GA 21,000	SC 30,000	PA 7,400	NJ 13,000	MI 7,500	CA 52,500
Problem nematodes						
Criconemella xenoplax	>70	80	Unkn.[y]	90	40	24
Pratylenchus vulnus	22	*[x]	*	*	*	24
P. penetrans	*	*	45-50	100	85	*
Meloidogyne spp.	45	50	Unkn.	*	40	22
Xiphinema spp.	*	*	100	25	60	*
Trichodorus spp.	*	*	*	10	*	*
Belonolaimus spp.	*	*	*	2	*	*
Hoplolaimus galeatus	*	*	*	*	<5	*
Longidorus elongatus	*	*	*	*	<5	*
% Annual loss	<1	6-8	2-3	3-5	15	9

[z]Numbers given for each nematode represent the % of the total acreage in that state infested.
[y]The distribution of *C. xenoplax* and *Meloidogyne* spp. is not known (Unkn.). Problems associated with these nematodes are very uncommon.
[x] *=Indicates that the nematode is either not found or when found not known to cause any damage.

Table 3. The percent of peach acreage treated with nematicide in each surveyed state and guidelines used to determine need for treatment.

	GA	SC	PA	NJ	MI	CA
% Acreage Treated						
1. Preplant	<1	20	Unkn.[Z]	90	50	50
2. Postplant	0	<10	Unkn.	50	35	<1
% Acreage Soil Sampled	1-2	10-20	<10	65-70	Unkn.	<1
Other Guidelines Recommended:						
1. Crop History	Yes	Yes	Yes	Yes	Yes	Yes
2. Soil Texture	Yes	Yes		Yes		
3. Location	Yes					
4. Orchard Age	Yes			Yes		
5. Orchard Health	Yes				Yes	

[Z]Unkn.=unknown.

Table 4. Population threshold of various nematodes used as a basis for nematicide recommendations in Michigan peach orchards.

Nematode Species	Threshold[Z]
Xiphinema americanum	5
Pratylenchus penetrans	100
Criconemella xenoplax	300
Meloidogyne hapla	50

[Z]Thresholds are number per 100 cm^3 soil for *X. americanum* and *C. xenoplax* and number per 100 cm^3 soil + 1 gram of root for *M. hapla* and *P. penetrans*.

SMALL PLOT EVALUATIONS OF VARIOUS NEMATICIDAL AGENTS

M.V. McKenry[1] and T. Buzo[2]

ABSTRACT

Different treatment rates of 3 natural plant products, 2 animal products, and 4 commercial fertilizers were compared for their nematicidal value against 3 commercial nematicides. The natural plant and animal products reduced populations of *Meloidogyne* spp. on young grapevines by as much as 60%, which was not a significant reduction ($P = 0.01$). Three of the commercial fertilizer treatments produced a significant reduction in nematode population levels with some reductions as much as 90% to 95% of the non-treated check. Post-plant treatments with fosthiazate nematicide reduced *Meloidogyne* population levels comparable to that of a pre-plant treatment of cis-1,3-dichloropropene (1,3-D). The different nematicidal agents had differing performance depending on the species of *Meloidogyne* present.

INTRODUCTION

Various compounds with nematicidal potential were screened for their performance against a diversity of nematode species in a microplot setting in 1990 and the best treatments were re-evaluated in 1991. The screening procedure consisted of planting a rooted grapevine into various nematode populations, in the month of April and then at 30 to 45 day intervals re-applying the nematicidal agent, usually via a dripper system. Soil and root nematode data were collected in October or November of that year.

MATERIALS AND METHODS

In a sandy loam soil (65% sand, 23% silt, and 12% clay) at the Kearney Agricultural Center 300 holes were dug 70-cm-diam and 1.3 m deep. A corrugated plastic tube 1.3 m length by 65 cm diam was inserted and the soil back-filled into place. The microplots were 1.4 m apart and each watered with a dripper emitter.

First-Leaf Vines

One-year-old rooted cuttings of *Vitis vinifera* cv. French Colombard were planted in April, 1991. Various nematode populations were in each series of microplots. Two hundred microplots contained a mixed population of *Meloidogyne* spp. Nematicide treatments were made at various intervals and rates depending on the product and previous experiments. Nematicides were added to each block of microplots in a completely randomized design with 10 replicates of each. For comparison, one treatment involved a 1,3-dichloropropene treatment in the previous fall and a second treatment involved soil with no nematodes present at planting time. Vines were dug in the fall months and their above-ground biomass determined.

Second-Leaf Vines

In one set of 100 microplots, 5 replicates of each of 4 *Meloidogyne* spp. and a non-inoculated check were allowed to grow in the presence of the nematodes for one year (1990) and then treated with each of 4 nematicide treatments in the second year (1991).

On grape, *M. hapla* is one of the more nomadic-species of *Meloidogyne* exhibiting small, superficial galls and producing relatively high soil to root ratios of juveniles which search for new root tips. They tend not to maintain old galls for lengthy periods and do not damage grape unless very high population levels are reached on young root systems. The *M. incognita* is Race 3, the cotton race, having large sized galls with multiple females present and providing high soil population levels. The *M. javanica* population is a pathotype from Thompson Seedless grapes, which can maintain large galls but tend to produce low soil population levels relative to root population

[1]M.V. McKenry, Nematologist, U.C. Riverside, 9240 S. Riverbend Ave., Parlier, CA 93648

[2]T. Buzo, Staff Research Assoc., U.C. Riverside, 9240 S. Riverbend Ave., Parlier, CA 93648

levels. It is possible that many juveniles of this pathotype seldom migrate through soil but stay within the root. There they successfully penetrate the giant cells developed by their mother. The fourth population, *M. arenaria*, is a pathotype of Cibola alfalfa near Blythe, CA. Little is known about it except that it can provide very large galls on alfalfa and can cause substantial damage to grape.

After one year of nematodes and grapevines together, the vines were treated with 3 sequentially spaced treatments of either Sincocin, a root protectant-type fatty acid, phenamiphos (Nemacur), an OP with some systemic activity, or fosthiazate, a true basipetally systemic nematicide. Nematodes in roots and soil around the roots were sampled in the fall of the second year.

RESULTS

Botanically Derived Nematicides

The 15,680 kg/ha (7 ton/acre) rate of sesame chaff from wild *Sesamum indicum* applied pre-plant gave a 63% population decrease of *Meloidogyne* (NS) (Fig. 1). A cold water extract of Cahaba White Vetch applied in 3 separate treatments at 45 day intervals with 36 g fresh plant material/liter of water in a 4 liter application gave a 60% reduction in the final *Meloidogyne* population. Sincocin is a fatty acid material combined with mined cytokinins and the extracts of 5 plant substances. It's nematicidal value is presumed to result from the fatty acids. Although data for the 2 repeated treatments appears spurious the 1x and 3x treatment levels gave at least 75% (NS) reductions in *Meloidogyne* population levels. As we will see later this effect is primarily a result of effectiveness on soil dwelling stages of *Meloidogyne*. Vantage vetch at 15,680 kg/ha (7 ton/acre) fresh refuse + 4,480 kg/ha of dried bug bodies provided a source of chitin, nitrogen and carbon for chitinase producing organisms. This treatment reduced root population levels of *Meloidogyne* by 80% (NS). This latter treatment perhaps deserves greater attention but an adequate supply of bug bodies presents a major limitation.

Commercial Fertilizers

Calcium nitrate, ammonium nitrate, urea ammonium nitrate (UAN-32), and regular biurette urea gave nematode population reductions of 68% (NS), 75% (NS against root populations but significant against soil populations), 89% and 90%, respectively. The latter two treatments provided significant nematode reductions from roots and soil. All the fertilizer treatments appeared to be detrimental to vine growth in the first 3 months after their application to young vines (Fig. 2).

Synthetic Nematicides

Repeated treatments of phenamiphos typically provide a better treatment than single treatments when the nematode is an endoparasite like *Meloidogyne*. In this case, 3 treatments with phenamiphos at 30-day intervals gave a 92% population reduction whereas single and double treatments did not give significant population reductions. The new nematicide, fosthiazate, applied at the same treatment intervals as phenamiphos gave 88%, 98%, and 99% population reductions at 1, 2, and 3 treatments, respectively. The indication is that re-treatment intervals of 30 days are not necessary with the compound. Only slight nematode contamination occurred across these plots as judged by the finding of a few nematodes in the no nematode treatment.

Vine Growth

The only treatment giving significant ($P = 0.05$) vine growth improvement was the standard pre-plant treatment of cis-1,3-D (Fig. 2). The fosthiazate treatment curled grape leaves in a manner very similar to the phloem-limited virus, grape leaf roll, however, vine growth did not appear to be impaired by repeated treatments at the 1 g/vine rate. The botanically derived and animal derived nematicidal agents were not

associated with reductions in vine growth, however the fertilizer salts were visually associated with vine growth reductions (NS). The untreated check vines did not receive any fertilization except the same amount of Osmocote slow release fertilizer that all treatments received.

Second-Leaf Vines

The Sincocin treatment reduced, but did not significantly affect nematode population levels using log-transformed values for nematodes/g of root (Fig. 3). However, non-transformed data for *M. hapla* (not shown) were significantly decreased at the 99% confidence level. The Sincocin treatments resulted in a darkened root appearance which was different from the check or nematode treatments. The phenamiphos treatments gave significant ($P = 0.01$) population reductions except in the case of the root-preferring *M. javanica* population. The fosthiazate treatment reduced nematode populations in roots regardless of the *Meloidogyne* spp. present and in spite of the fact that the vines had been given one year for nematode populations to build-up within the roots. Each of the three nematicide applications to second-leaf vines gave numerically improved vine growth, but none were significantly improved over the appropriate treated check (Fig. 4).

CONCLUSIONS

A longer term test will be needed to obtain significant growth differences in the presence of nematicidal treatments. Sincocin appeared to stimulate some type of root surface protection against the nematodes. This fatty acid treatment caused general reductions in their numbers but was most effective against the ectoparasitic stages. Phenamiphos reduced populations consistently, but was less effective on root inhabiting stages. Fosthiazate was effective on root and soil populations of *Meloidogyne* spp. Certain fertilizer treatments, especially UAN-32, effectively reduced nematode populations when applied at 30- to 45-day re-treatment intervals with 10 to 15 units of N each time via a dripper. Tests of longer duration are underway.

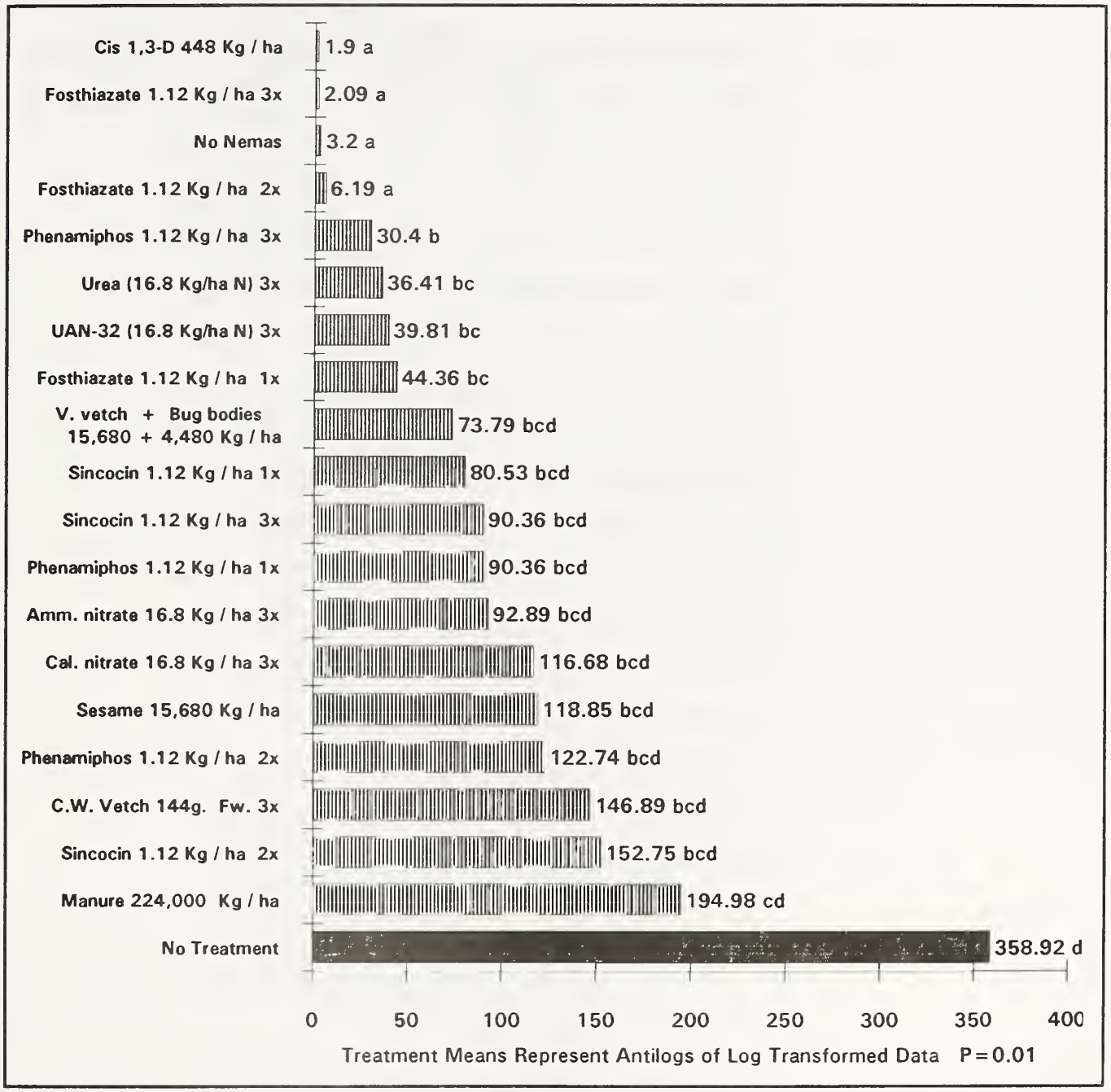


Figure 1. Reduction of a *Meloidogyne* root population with the use of various nematicidal agents.

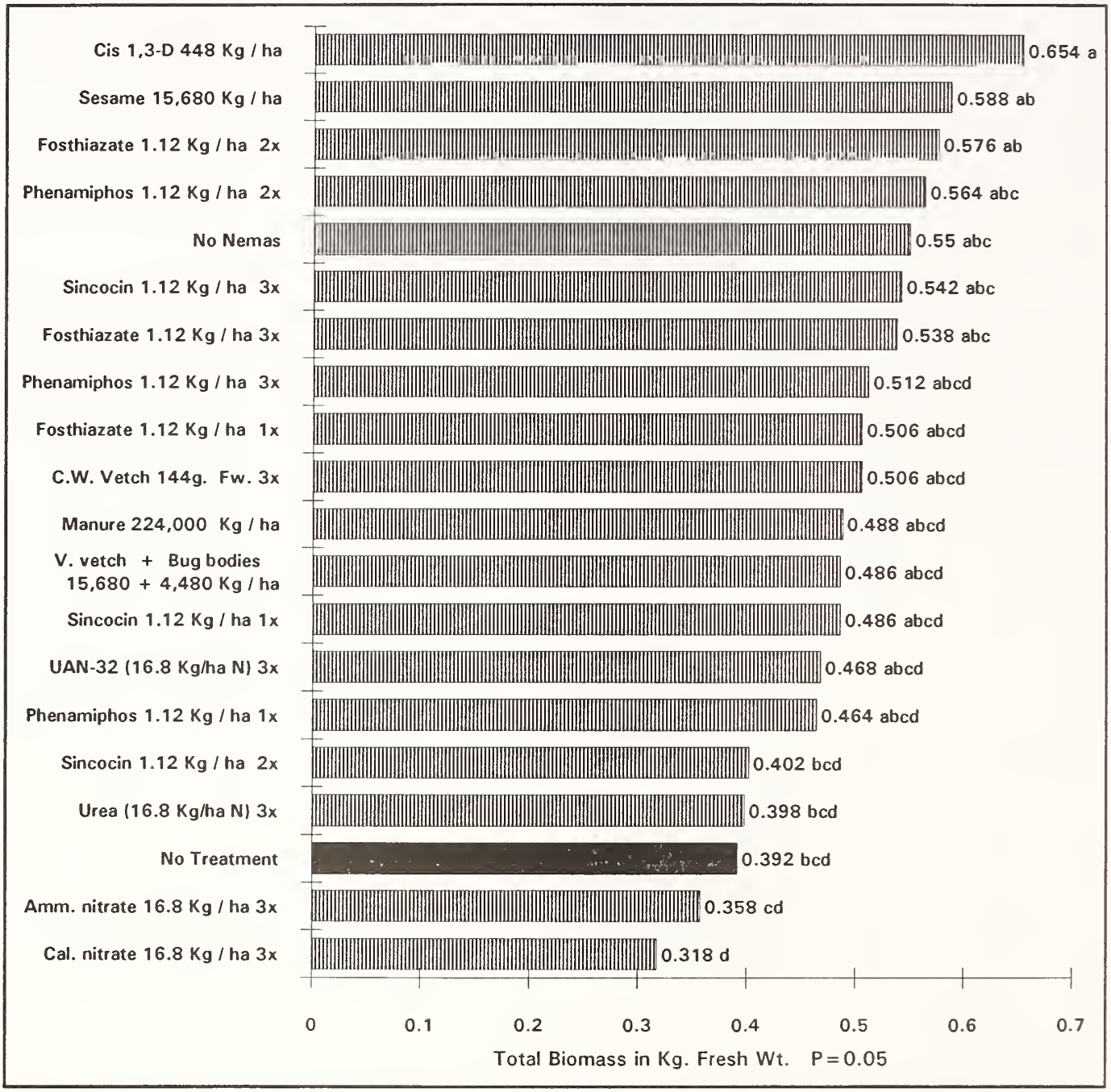


Figure 2. Growth response with the use of various nematicidal agents.

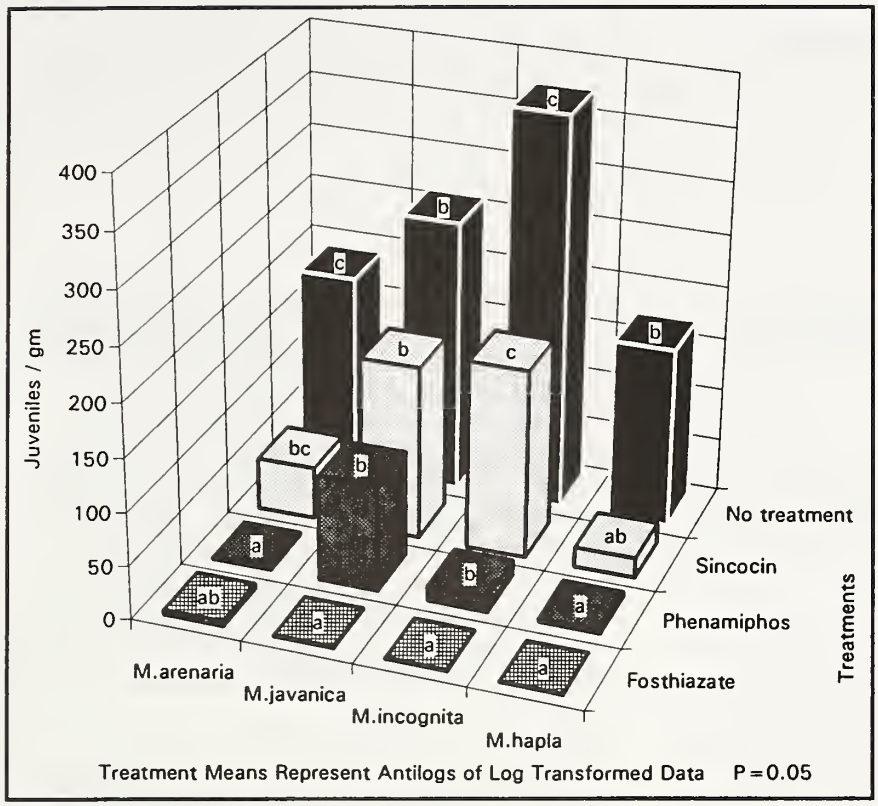


Figure 3. Population levels of four *Meloidogyne* spp./gram of grape root 150 days after the last of three 1.12 kg/ha. treatments via a dripper.

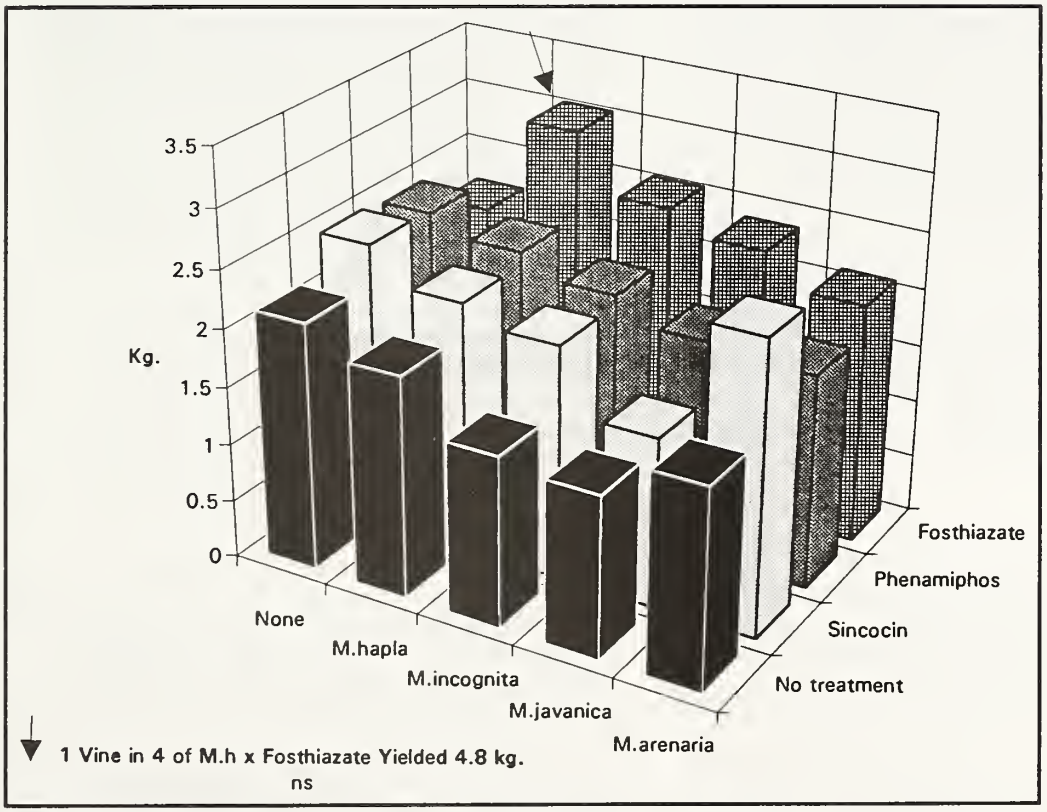


Figure 4. Total biomass produced in 1 year from a 2nd-leaf grapevine.

PHOMOPSIS DIEBACK OF PEACH SHOOTS

A.J. Latham[1]

An epidemic of shoot dieback occurred in 75% of the peach orchards in central Alabama during 1991. The pathogen was identified as the *Phomopsis* anamorph of *Diaporthe perniciosa* Marchal (syn. *Phoma persicae* Schulzer & Sacc.) (Latham et al., 1992). *Phomopsis* dieback has become a problem of increasing importance for Alabama growers since fruiting wood of susceptible peach cultivars is destroyed by the disease.

Phomopsis dieback was originally described as constriction disease by Selby (1898), with further elaborations by Roberts (1940). It has also been known as Fusicoccum canker (Guba, 1953), and in Europe as "die back" (Cayley, 1923). The severity of this disease was indicated by Daines (1966). He reported infected peach twigs were usually girdled resulting in death of the distal portion. Such cankers could result in the death of young trees, while older trees lost much of their bearing wood. It was not uncommon for a peach crop to be reduced more than 50% in bearing orchards of susceptible varieties. During the 1940's, thousands of trees were uprooted and many farms went out of peach production in south New Jersey because of the destructive nature of this disease (Daines, 1966).

Other researchers have reported minor fruit disease problems caused by the *Phomopsis* dieback pathogen, e.g., peach rot (Daines and Peterson, 1976) and core rot of stored apple fruit (Rosenburg and Burr, 1982).

SYMPTOMS

One-year-old peach shoots infected by the pathogen have chlorotic, light brown, wilted leaves with an overall dying appearance. One or more cankers girdling the shoot are located below the necrotic leaves. Cankers are centered on sunken, dormant lateral buds or leaf scars and are light-tan to gray in color, becoming brown at the periphery. A concentric ring pattern is visible and a clear to amber-colored gum may cover the canker surface. Numerous pycnidia submerged in the bark appear dark colored where the tissue has been ruptured to exude pycnospores. In a moist atmosphere, conidia exude together in long cream-colored spore tendrils called cirrhi. Blighted flower clusters are also associated with cankers on some trees.

MATERIALS AND METHODS

During April 1991, extensive dieback symptoms were observed in a 1,600 tree block near Thorsby, Chilton County comprised of several cultivars of peaches planted during the winter of 1978. Over the past few years, wettable sulfur had been applied for control of brown rot, caused by *Monilinia fructicola*. Since the trees were old and replanting was scheduled, applications of nitrogen had been omitted, but potassium and phosphorus applications had been continued. On the day we visited the *Phomopsis* dieback orchard, several hundred trees in an adjoining orchard had been pushed-up and piled for burning. These trees had sustained cold damage resulting from freezing periods that occurred during the winter of 1989.

Our initial observations indicated dieback was limited to overwintered fruiting wood. On 24 April, 1991, diseased and healthy shoots were counted on one limb per tree on each of four randomly selected trees per cultivar. On 17 May, 1991, fresh, bright-brown lesions were found at the base of current season juvenile branch shoots.

During April and May, 1991, an abundance of rain was recorded in Chilton County at the Chilton Area Horticulture Substation located 2.8 km from the orchard being studied.

A fungicide test was set up on 'Sentinel' trees starting 22 October, 1991. Three tree replicates were used per fungicide treatment, which consisted of Bravo 720, Lime Sulfur, or Nova 40

[1]Department of Plant Pathology, Alabama Agricultural Experiment Station, Auburn University, AL 36849

WP. Applications were made with an air-blast sprayer. All viable and diseased shoots on two scaffold limbs per tree were counted 3 March, 1992.

The effects of temperature on *in vitro* growth of the *Phomopsis* dieback fungus were determined in the laboratory. Mycelial-agar discs, 5-mm-diam, of a pure 4-day-old culture of *Phomopsis* on potato dextrose agar (PDA) were placed in the center of 20 ml PDA plates and incubated at 5 C intervals from 5 C through 35 C. Colony diameters were measured daily for four days.

Laboratory tests were also initiated to evaluate fungicides against the *Phomopsis* dieback pathogen. Shoots of 'Jerseyqueen' peach were cut to 10.7 cm, soaked five minutes in 1.25 g Omit plus 0.29 g Guthion/L, and washed six times in tap water. The shoots were dipped in a suspension of fungicide then laid on a clean paper towel to dry. Subsequently, the shoots were sprayed to wetness with an aqueous suspension 4.8×10^5 *Phomopsis* conidia/ml; unsprayed shoots were included to serve as controls. Treated and control peach shoots were placed in the same Pyrex storage dishes (100 x 80 mm) that contained two Whatman #2 filter papers soaked with 3 ml sterile water, and incubated at 25 C, and 12 hr light for 21 days. Approximately 3 ml sterile water was added every 3 to 5 days to maintain high relative humidity in the storage dishes. Fungicides that showed good control were retested separately and in combinations at 18 C.

RESULTS AND DISCUSSION

According to Roberts (1940), only old, devitalized or injured peach trees were affected by *Phomopsis* dieback in Delaware. He also reported peach trees in a high state of vigor were not attacked. Our observations confirmed that *Phomopsis* dieback affected old devitalized trees. However, on the Chilton Area Horticulture Substation, some branches on vigorous 3-yr-old 'Loring' and 'Redhaven' trees also had *Phomopsis* dieback. During 1991, *Phomopsis* dieback was a wide-spread problem, regardless of tree age and cultivar throughout Chilton County.

The incidence of *Phomopsis* dieback in the Chilton County orchard 24 April, 1991 by cultivar was: Sentinel 96%, Coronet 89%, Redhaven 88%, Topaz 80%, Loring 73%, Harvester 71%, Sure Crop 56%, Dixie Land 19%, and Redskin Elberta 5% (Table 1). An abundance of rainfall during April and May (Table 2) apparently had a significant effect on disease development. Presumably, pycnospores of *Phomopsis* were washed down the necrotic shoots and subsequently germinated and infected juvenile secondary branches at the site of emergence from the main shoot. These secondary infections resulted in the death of additional shoots, thereby preventing much fruit wood development for 1992.

Phomopsis dieback had been a problem in this orchard for several years. The grower had used wettable sulfur for control of brown rot. Hagan (1991) wrote that constriction disease had been seen sporadically on peaches in South Carolina and Georgia, but apparently had little impact on crop quality and yield. He speculated that lower levels of *Phomopsis* dieback on their fruit trees may have been related to greater use of Captan. We established a test in the 'Sentinel' peach block to evaluate some of the newer generation of fungicides; however, results indicate no significant control of *Phomopsis* dieback (Table 3). Perhaps greater disease incidence and possibly more evident effects might have occurred had the grower not pruned the trees earlier.

Some peach workers do not believe *Phomopsis* dieback can be controlled with fungicides and suggest that the only effective means of control is through sanitation procedures (Hendrix, 1991) and/or use of resistant cultivars (Weaver, 1951). According to Daines (1966), Bordeaux mixture, commercial coppers, wettable sulfur, lime sulfur, Captan, Glyodin, Phygon and the carbamates were ineffective in controlling *Phomopsis* canker. However, he showed that three spray applications of either phenyl mercury

or Bordeaux-lead arsenate at 20-day intervals beginning about September 8 provided highly effective control of the disease.

Initial *in vitro* screens for fungicide activity were made at 25 C since culture tests had shown that to be the optimal temperature for growth of *Phomopsis* (Fig. 1). Results indicated that Baycor 50 WP, Bravo 720, Captan 50 WP, and Orbit 3.6 EC might be effective for control of *Phomopsis* (Table 4). Subsequent laboratory tests at 18 C, a temperature approximating that found in the orchard during October and November, confirmed the fungicidal activities of Bravo and Orbit (Table 5). Results also indicated that Nova 40 WP had strong activity against *Phomopsis*. Based on these results, tests were established on the Chilton Area Horticulture Substation in September 1992 to evaluate their efficacy at standard and 2X rates of application.

LITERATURE CITED

Cayley, C.M. 1923. Fungi associated with "die back" in stone fruit trees. Ann. Applied Biol. 10:253-274.

Daines, R.H. 1966. Peach canker (*Fusicoccum amygdali*) and its control. Hort. News 47:14-17.

Daines, R.H. and J.L. Peterson. 1976. The occurrence and control of phomopsis fruit rot of peach. Plant Dis. Rep. 60:141-143.

Guba, E.F. 1953. Large leaf spot and canker of peach caused by the fungus *Fusicoccum amygdali* Delacr. Plant Dis. Rep. 37:560-654.

Hagan, A.F. 1991. Constriction disease threatens peaches. AL Coop. Ext. Serv. Auburn Univ., Pp. 226. 3 pp.

Hendrix, F. (ed.) 1991. Georgia fruit newsletter. Univ. GA, Coop. Ext. Serv. Feb. 11 Pp.

Hopfinger, J.A. 1991. Commercial tree fruit production--Recommendations for New Jersey. Rutgers Coop. Ext., NJ Agr. Expt. Sta. EOO2G.

Latham, A.J., G. Morgan-Jones and H.L. Campbell. 1992. *Phomopsis* dieback of peach shoots in Alabama. Plant Dis. 76:426.

Roberts, J.W. 1940. The constriction disease of peach. Phytopathology 30:963-968.

Rosenberger, D.A. and T.J. Burr. 1982. Fruit decays of peach and apple caused by *Phomopsis mali*. Plant Dis. 66:1073-1075.

Selby, A.D. 1898. Preliminary report upon diseases of the peach. Constriction disease of stem and branch. OH Agr. Expt. Sta. Bul. 92:233-234.

Weaver, L.O. 1951. The constriction disease of peach in Maryland. Plant Dis. Rep. 35:144.

Table 1. Peach cultivars reported to be susceptible to *Phomopsis* dieback.

Alabama[z,y]	New Jersey[x]	Massachusetts[w]	Other
Brighten	Blake	Belle of Georgia	Babygold[v]
Coronet	Derby	Cumberland	Golden Jubilee[u]
Dixieland	Erly-Red-Fre	Eclipse	
Dixired	Jerseyland	Greensboro	
Encore	Jerseyqueen	June Elberta	
Harvester	Redhaven	Raritan Rose	
Keystone	Rio-Oso-Gem	Summercrest	
Loring	Slaybaugh		
Majestic	Sunqueen		
Redhaven	Triogem		
Sentinel			
Surecrop			
Sunland			
Topaz			

[z]Research of J.A. Pitts, Supt. Chilton Area Hort. Substn. and R.T. Boozer, Assoc. County Agent, Chilton County, AL.
[y]Reported in Latham et al., 1992.
[x]Reported in Hopfinger, 1991.
[w]Reported in Guba, 1953.
[v]Correspondence by J. A. Pitts with Dr. Floyd Hendrix, Univ. of Georgia.
[u]Reported in Weaver, 1951.

Table 2. Rainfall recorded at Chilton Area Horticulture Substation.

	Rainfall (inches)		
Month	1990	1991	1992
January	10.86	5.73	4.87
February	8.74	5.01	6.66
March	10.65	6.14	2.86
April	2.18	8.04	3.18
May	4.48	11.01	1.32
June	0.52	7.25	2.21
July	3.13	2.12	7.41
August	0.93	0.75	5.98
September	0.28	3.98	3.59
October	3.26	0.78	---
November	2.91	3.99	---
December	4.31	2.57	---
Total	52.25	57.37	38.08

Table 3. Evaluation of fungicides for control of Phompsis dieback of 'Sentinel' peaches, Chilton County, Alabama.

Fungicide and rate/A	Application schedule	Shoots with *Phomopsis* symptoms (%)[z]
Bravo 720 (3 1/8 pt)	Fall[y]	22.0 a[v]
Bravo 720 (3 1/8 pt)	Fall and Spring[x]	14.0 a
Lime Sulfur (12 gal)	Fall, 50% leaf fall	19.6 a
Lime sulfur (12 gal)	Dormant[w]	14.0 a
Nova 40 W	Fall	15.3 a
Nova 40 W	Fall and Spring	14.7 a
Control ---	Fall and Spring	29.0 a

[z] Determined on two scaffold limbs from three tree replicates 3 March, 1992.
[y] Fall, three applications at 3-week intervals beginning 22 October, 1991.
[x] Spring, one application at pink bud, full bloom, and petal fall.
[w] Dormant, one application when buds showed color.
[v] Numbers followed by same letter do not differ significantly according to DMRT (P=0.05).

Table 4. Laboratory evaluations of fungicides for control of *Phomopsis* dieback of 'Jerseyqueen' peach shoots.

Fungicides	Rate/ liter	% Peach shoots with symptoms and signs[z]
Baycor 50 WP	0.59 g	11
Benlate 50 WP	0.59 g	100
Bravo 720	4.99 ml	22
Captan 50 WP	2.39 g	89
Dikar 80 WP	2.39 g	100
DuTer 47.5 WP	2.39 g	100
Liquid Lime- sulfur	18.92 ml	100
Orbit 3.6 EC	0.47 ml	56
Rovral 50 WP	1.59 g	100
Sulfur 90 WP	7.19 g	100
Topsin M 70 WP	0.29 g	100
Control	----	100

[z] Symptoms: pale tan bark, sunken concentric ring pattern usually present and surrounding dead bud or leaf scar; Signs: pycnidia and/or cirrhi in canker. Incubation was 3 wk at 25 C.

Table 5. Laboratory evaluations of selected fungicides for control of *Phomopsis* dieback of 'Jerseyqueen' peach shoots.

Fungicide	Rate/liter	Disease ratings[z]	
		Fungicide	Check
Bravo 720	4.9 ml	1.50	5.38
Bravo 720	9.9 ml	1.38	5.38
Nova 40 WP	2.39 g	1.25	5.50
Nova 40 WP	4.78 g	2.25	5.63
Orbit 3.6 EC	0.46 ml	1.25	5.50
Orbit 3.6 EC	0.92 ml	1.25	5.25
Bravo 720 + Nova 40 WP	4.9 ml 2.39 g	1.25	5.50
Bravo 720 + Nova 40 WP	9.9 ml 4.8 g	1.50	5.50
Bravo 720 + Orbit 3.6EC	4.9 ml 0.46 ml	1.25	5.13
Bravo 720 + Orbit 3.6 EC	9.9 ml 0.92 ml	1.63	5.25

[z] Ratings key: 1=green shoot + bud swell and leaf emergence; 2=green shoot plus brown diseased section; 3=shoot brown from disease; 4=zonate lesion; 5=pale, tan bark; 6= *Phomopsis cirrhi* and pycnidia. Data from two fungicide-treated shoots and two checks in each of 4 dishes. Shoots were retreated at 2-week intervals; evaluations made after 5-weeks at 18 C.

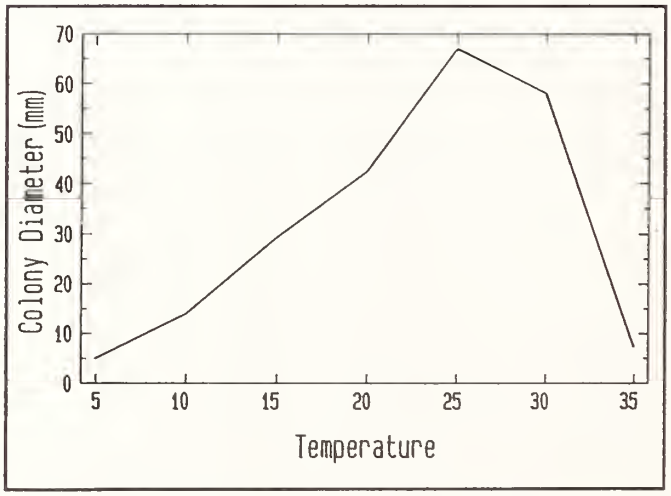


Figure 1. Growth of *Phomopsis* sp. on Potato Dextrose Agar after 96 hrs.

ESTIMATED PEACH TREE LOSSES 1980 TO 1992 IN SOUTH CAROLINA-CAUSES AND ECONOMIC IMPACT

R.W. Miller[1]

INTRODUCTION

In 1979, the nematicide 1,2 dibromo-3-chloropropane (DBCP) was canceled and suspended for use on peaches. The ring nematode [*Criconemella xenoplax* (=*Mesocriconema xenoplax*)] had been demonstrated during the Seventies to be a major causal factor in the peach tree short life (PTSL) complex. Because of the loss of DBCP and lack of adequate alternative control strategies it was suspected that peaches would suffer significant losses. An effort was initiated, in part, to determine the impact of the loss of DBCP.

The peach industry is important to the agriculture economy of South Carolina. It is generally the fifth largest crop in the state. Several diseases severely impact the life of an orchard reducing current and future production as well as profitability as an agricultural enterprise.

Research priorities should be set so as to have maximum impact with scarce resources. Two attributes are important in setting research priorities. They are: which diseases are having maximum negative impact on production and profitability and where will the application of resources yield usable information on reducing the impact of disease most rapidly.

No research resources have been completed to regularly document the extent and severity of disease that results in tree death in South Carolina. References in the literature regarding tree losses, represent the opinion of professional peach workers. They do not segregate causes, and their estimates were not done in a regular fashion.

The Extension peach pathology program maintains a cadre of individuals who are competent in the diagnosis of disease. The existence of a body of technology which reduces or manages the risk associated with the operation of a peach enterprise is necessary both for these individuals and to maintain the competitive edge of the peach enterprise.

The main objective of this program is to assist with research priority setting both with respect to other commodity programs as well as within the peach research effort. This is an update to the original paper presented at the Stone Fruit Decline Workshops in 1986 and 1990 and also embodies some of the same data presented then. Some of the data shown here has changed from that presented in 1990 due to the availability of better enumeration figures.

MATERIALS AND METHODS

Annual observations and opinions of trained professional peach workers, both public and private, are amassed to create estimates below. Information used, varies with year and programs in effect. Sources include records and observations of public and private scouts, plant pest regulatory personnel, county and area agents, pesticide industry personnel, and those of the author. The usual pattern is for the experienced observer to drive wide middles developing an individual estimate for each orchard.

RESULTS

An average of 142,479 trees are lost annually, ranging from a low of 75,000 to a high of 284,280 trees (Tables 1 and 2). For the 13-year period from 1980 to 1992 inclusive, a total loss in potential income was $140,703,530 (Table 2). Peach tree short life represents $84,772,044 of this loss or over $6.52 million per year (Table 2). Oak root rot represents $50,176,641 or over $3.86 million annually (Table 2). Crown root rot results in much less damage or about $0.83 million per year.

[1]Professor, Plant Pathology and Physiology, 206 Long Hall, Clemson University, Clemson, SC 29634

Regional differences are apparent from the observations. Peach tree short life is the most frequent cause of death in the Ridge area of the state followed by the Coastal Plains and the Piedmont (Table 1). Oak rot rot is the most severe in the Piedmont followed by the Coastal Plains and then the Ridge (Table 1). The severity in individual years varies widely and reflects weather in the region.

Diseases caused by fastidious microorganisms are more significant in the Coastal Plains with phony peach being the most significant. When all other problems are lumped together their impact is small compared to the diseases above. The exception is natural disasters like Hurricane Hugo which increased tree loss by 80% or about 40,000 trees in the Coastal Plains (Table 1 and 2).

DISCUSSION

The most severe problem facing the peach industry is reliable cropping. Yields have varied from 80 million pounds to 400 million pounds. During the past 10 years spring frosts, which are most frequent and severe in the Piedmont and least in the Coastal Plains, have been the cause of poor cropping reliability. This has resulted in a number of peach farm failures and reduced planting of peaches, hence, the decline in the number of trees during this period in the Piedmont Region.

The risk associated with cropping reliability interacts with the data in a number of different ways. The application of technology requires increasing investment in either purchased inputs, (such as Nemacur) or management (such as IPM scouting). Growers who are exposed to high risks, such as frosts, are unwilling to increase their investment in disease control.

Nemacur, which became available in the early 1980's with a Section 18 of amended FIFRA for control of ring nematode and, hence, PTSL, has not been adopted by the growers for this reason. This has resulted in a change in the age distribution of the peach population. The large number of trees in the susceptible age range of PTSL (1 to 7 years) is probably reflected in the large number of trees to die between 1983-1985. During this same period the ring nematode was probably increasing in population while the trees were susceptible. Lower number of tree deaths in the last 5 years is probably a result of this age distribution as well as a 1 million reduction in number of trees. The continued planting in the Ridge area to make up for tree losses also reflects increasing tree density per acre. More young trees are resulting in an increase in number of trees dying from PTSL. Although increasing, it is not reaching levels of the mid-1980's possibly because of increased use of Lovell rootstock. There has been virtually 100% adoption of this rootstock.

In the same thinking (greater exposure time), the average age of trees increased during the period of the late 1970's resulting in a larger number of individuals that were at risk for oak root rot. This and the observation above, about age distribution, is probably associated with the sustained losses to oak root rot in the Piedmont is most likely interacting with the ring nematode. The ring nematode reproduces slower in the heavier soils of the Piedmont. As a result, the incidence of PTSL is lower in the Piedmont and trees are exposed to oak root rot risk longer.

Many observers have noted an apparent association of the oak root rot with the more poorly drained sites on a statewide basis. Some have hypothesized that "wet feet" or crown rot or both may be a significant interacting factor in the amount of oak root rot observed. At least two strains of oak root rot are present as indicated by carpophores with and without annulus.

Phythophthora cinnamomi is constantly associated with crown root rot in South Carolina. Crown rot is associated with poorly drained sites. It may be more significant than the figures indicate. The development of low pressure targeted frost control systems through "icing down" and adoption of other frost control

technology like wind machines could impact on this problem in the future.

The tree death considered here is the tree that collapses prematurely. Not considered here under "other" is the slow decline that is associated with sapwood and heart rot invaders. These trees usually lose a branch at a time as a result of crop load causing limb breakage. Such damage is removed annually so numbers remain low especially when trees die of other causes such as PTSL. Slow decline is associated with cold injury, wounds, improper pruning, and other stresses. Viruses are not considered here as they cause a branch dieback, cracks in the bark, excessive sprouting and are also part of the slow decline complex. Also not considered is gummosis (*Botryosphaeria dothidea*). The impact of gummosis is unknown. This disease is now considered widespread in the Ridge area, especially Edgefield County.

Table 1. Estimated cause of premature peach tree death in the three regions of South Carolina, 1980–1992. (Percentages are the % of dead trees by region attributed to various causes).

Region and Counties	Cause	1980	1981	1982	1983	1984	1985	1986
Piedmont	Short life	37%	15%	59%	7%	14%	16%	25%
Oconee	Oak root rot	36%	83%	39%	91%	70%	64%	54%
Pickens	Crown rot	24%	1%	Trace	Trace	13%	16%	17%
Greenville	Viruses et al.[z]	Trace	Trace	Trace	1%	Trace	Trace	Trace
Spartanburg	Other[y]	3%	1%	2%	Trace	3%	4%	3%
Cherokee								
Laurens								
York								
Trees in Region[x]		1,600,000	1,600,000	1,600,000	1,850,000	1,850,000	1,811,000	1,400,000
Percent Trees Dead		1.5	2.7	2.2	6.4	3.5	3.0	3.2
Ridge	Short Life	60%	93%	96%	77%	88%	83%	87%
Aiken	Oak root rot	20%	6%	3%	20%	10%	14%	11%
Edgefield	Crown rot	10%	Trace	Trace	2%	1%	2%	2%
Saluda	Viruses et al.	Trace	Trace	Trace	Trace	Trace	Trace	Trace
Lexington	Other	9%	Trace	Trace	Trace	Trace	Trace	Trace
Chesterfield								
Trees in Region		1,300,000	1,430,000	1,500,000	1,713,000	1,713,000	1,680,000	1,700,000
Percent Trees Dead		3.4	2.1	3.6	8.8	9.5	9.1	4.8
Coastal Plains	Short Life	60%	50%	30%	90%	23%	31%	26%
Barnwell	Oak root rot	20%	37%	41%	2%	22%	28%	49%
Allendale	Crown rot	10%	3%	Trace	4%	28%	30%	14%
Hampton	Viruses et al.	1%	4%	3%	4%	3%	3%	4%
Orangeburg	Other	6%	5%	26%	Trace	24%	8%	7%
Sumter								
Other								
Trees in Region		340,000	414,000	420,000	440,000	460,000	515,000	520,000
Percent Trees Dead		2.0	1.8	1.5	3.4	1.9	2.4	2.1
Total Trees in State		3,240,000	3,444,000	3,520,000	4,002,000	4,002,000	3,950,000	3,650,000
Total Percent Trees Dead		2.3	2.2	2.4	6.2	4.9	5.6	3.8

Table 1 (Continued)

Region and Counties	Cause	1987	1988	1989	1990	1991	1992	Avg.
Piedmont	Short life	25%	28%	17%	14%	7%	5%	12%
Oconee	Oak root rot	60%	55%	61%	66%	65%	60%	62%
Pickens	Crown rot	15%	12%	18%	16%	15%	20%	16%
Greenville	Viruses et al.[z]	Trace	Trace	<1%	Trace	<1%	2%	<1%
Spartanburg	Other[y]	0%	5%	3%	4%	12%	13%	4%
Cherokee								
Laurens								
York								
Trees in Region[x]		1,360,000	909,000	875,000	909,000	866,000	850,000	
Percent Trees Dead		4.0	4.0	4.2	5.1	3.1	2.3	
Ridge	Short Life	85%	77%	75%	65%	75%	68%	79%
Aiken	Oak root rot	11%	17%	8%	23%	14%	13%	13%
Edgefield	Crown rot	2%	1%	17%	7%	3%	9%	5%
Saluda	Viruses et al.	Trace	Trace	Trace	Trace	Trace	Trace	Trace
Lexington	Other	Trace	4%	4%	5%	8%	10%	3%
Chesterfield			75%					
Trees in Region		1,650,000	1,759,000	1,730,000	1,700,000	1,746,000	1,700,000	
Percent Trees Dead		2.5	2.3	4.0	2.0	5.8	5.1	
Coastal Plains	Short Life	26%	43%	46%	7%	28%	23%	37%
Barnwell	Oak root rot	57%	43%	46%	20%	43%	39%	34%
Allendale	Crown rot	7%	10%	2%	12%	10%	17%	11%
Hampton	Viruses et al.	4%	4%	5%	3%	<1%	<1%	3%
Orangeburg	Other	6%	Trace	1%	58%[w]	18%	20%	14%
Sumter								
Other								
Trees in Region		525,000	525,000	535,000	550,000	577,000	580,000	
Percent Trees Dead		2.1	1.8	2.0	8.0	6.0	4.0	
Total Trees in State		3,525,000	3,193,000	3,140,000	3,159,000	3,184,000	3,130,000	
Total Percent Trees Dead		2.8	2.7	3.4	5.0	4.9	3.8	

[z]Includes Fastidious bacterial diseases, yellows, rosette, phony, as well as viruses PNRSU, stem pitting (see discussion).
[y]Includes *Oryporus latemarginatus, Ganoderma lucidum*, Sapwood polypores and heart rot fungi (see discussion).
[x]Tree census data available for years 1982, 1985, 1988, and 1991. The numbers reported include estimated trees planted, abandoned or pushed up.
[w]Hurricane Hugo damage.

Table 2. Estimated value of peach tree losses 1987-1992 and in lifetime productivity for South Carolina[z].

Estimated Losses by Region	No. Dead Trees	Value of Dead Trees	Value of Losses to Short Life	Value of Losses to Oak Root Rot	Value of Losses to Crown Rot	Value of Losses to Other Causes
State Total:						
1987	106,675	952,300[y,w]	536,398	324,861	67,911	13,230
Lifetime		8,000,625[x]	3,864,672	3,259,631	731,756	82,687
1988	86,267	1,035,204[w]	544,755	371,179	68,553	45,771
Lifetime		6,470,025	3,404,714	2,320,439	428,457	285,071
1989	116,650	985,280[w]	561,944	255,344	150,648	39,569
Lifetime		8,748,750	4,730,212	2,465,662	1,394,475	338,438
1990	123,900	922,265[w]	203,532	274,439	107,317	324,435
Lifetime		9,292,500	2,370,450	3,518,550	1,125,300	2,179,200[v]
1991	162,444	1,565,816	814,825	426,903	105,046	181,624
Lifetime		12,183,300	6,467,974	3,485,507	789,068	1,340,817
1992	129,450	915,900[w]	423,633	246,582	117,606	112,949
Lifetime		9,708,750	4,895,213	2,403,675	1,171,275	1,188,863
6 year total	762,386	6,376,765	3,085,087	1,935,308	617,081	727,278
Lifetime		54,403,950	25,733,235	17,453,464	5,640,331	5,415,076
Grand Subtotal		60,780,715	28,818,322	19,388,772	6,257,412	6,142,354
Piedmont:						
1987	54,500	325,000	81,250	195,000	48,750	0
Lifetime		4,080,000	1,020,000	2,448,000	612,000	0
1988	36,360	436,320	122,170	239,976	52,358	21,816
Lifetime		2,727,000	763,560	1,499,850	327,240	136,350
1989	36,750	241,000[w]	40,970	147,010	43,380	7,230
Lifetime		2,756,250	468,562	1,681,312	496,125	82,668
1990	45,900	181,764[w]	25,447	119,964	29,082	7,270
Lifetime		3,442,500	481,950	2,272,050	550,800	137,700
1991	26,846	241,614[w]	16,912	157,049	36,242	29,994
Lifetime		2,013,450	140,941	1,308,743	302,018	241,614
1992	19,550	117,300[w]	5,865	70,380	23,460	15,249
Lifetime		1,466,250	73,313	879,750	293,250	190,613
6 year total	219,906	1,542,998	292,614	929,379	233,272	81,559
Lifetime		16,485,450	2,948,326	10,089,705	2,581,433	788,965
Grand Subtotal		18,028,448	3,240,940	11,019,084	2,814,705	870,524

Table 2. (Continued)

Estimated Losses by Region	No. Dead Trees	Value of Value of Dead Trees	Value of Losses to Short Life	Value of Losses to Oak Root Rot	Value of Losses to Crown Rot	Losses to Other Causes
Ridge:						
1987	41,250	495,000[W]	420,750	54,450	9,900	0
Lifetime		3,093,750	2,629,688	340,631	61,875	0
1988	40,457	485,484[W]	373,823	82,532	4,855	19,419
Lifetime		3,034,275	2,336,392	515,827	30,342	120,371
1989	69,200	615,880[W]	461,910	49,270	104,700	24,635
Lifetime		5,190,000	3,892,500	415,200	882,300	207,600
1990	34,000	212,500[W]	138,125	48,875	14,875	10,625
Lifetime		2,550,000	1,657,500	586,550	178,500	125,500
1991	100,978	908,802	681,601	127,232	27,264	72,704
Lifetime		7,573,350	5,600,013	1,060,269	227,200	605,868
1992	86,700	520,000[W]	353,736	67,626	46,818	52,020
Lifetime		6,502,500	4,421,700	845,325	582,225	650,250
6 year total	372,585	3,327,866	2,429,945	355,685	208,412	179,403
Lifetime		27,943,875	20,637,793	3,763,802	1,962,442	1,711,589
Grand Subtotal		31,181,741	22,967,738	4,119,487	2,170,854	1,730,992
Coastal Plains:						
1987	11,025	132,300	34,398	75,411	9,261	13,230
Lifetime		826,875	214,987	471,319	57,881	82,687
1988	9,450	113,400	48,762	48,672	11,340	4,536
Lifetime		708,750	304,762	304,762	70,875	28,350
1989	10,700	128,400	59,064	59,064	2,568	7,704
Lifetime		802,500	369,150	369,150	16,050	48,150
1990	44,000	528,000	39,960	105,600	63,360	306,240
Lifetime		3,300,000	231,000	660,000	396,000	1,914,000[V]
1991	346,920	415,400	116,312	178,622	41,540	78,926
Lifetime		2,596,500	727,020	1,116,495	259,650	493,335
1992	23,200	278,400[W]	64,032	108,576	47,328	55,680
Lifetime		1,740,000	400,200	678,600	295,800	348,000
6 year total	132,995	1,595,900	362,528	575,945	166,136	466,316
Lifetime		9,974,625	2,247,119	3,675,737	1,096,256	2,914,522
Grand Subtotal		11,570,525	2,609,647	4,251,682	1,262,392	3,380,638

[Z]Based on data by Bauer, 1978, "Costs and Returns of Producing Peaches in South Carolina". Special bulletin 617, Agricultural Economics Department, Clemson University, Clemson, SC 29634.
[Y]Based on $6.00 per 3/4 bu and 1 1/2 marketable bu/tree. Actual yield for bearing trees may vary.
[X]Based on eight-year-old tree at 9 percent discount rate.
[W]Value reduced because of spring freeze in region which reduced crop.
[V]Hurricane Hugo increases this value.
Data from 1980-1986 is available in the Proceedings of the 1990 Stone Fruit Decline Workshop.

WOOD DECAY, LIGNICOLOUS FUNGI, AND DECLINE OF PEACH TREES IN SOUTH CAROLINA

J.E. Adaskaveg[1], R.W. Miller[2] and R.L. Gilbertson[3]

In the fall of 1989, a survey for lignicolous fungi and wood decay was conducted in twenty-four peach (*Prunus persica* L.) orchards in the Coastal, Ridge, and Piedmont regions (8 orchards per region) of South Carolina. Twenty-four hundred trees, averaging 12.5 years old, were evaluated for decay fungi; while 480 trees were evaluated for incidence, severity, and type of decay. Thirty-nine species in 30 genera were collected: 17 are new reports on peach in South Carolina, while 14 species are new reports on peach in North America. White-rot fungi were most commonly collected and included species in the following genera: *Armillaria, Ganoderma, Laeticorticium, Oxyporus, Schizophyllum, Schizopora, Stereum, Trametes,* and *Trichaptum*. Species of brown rot fungi collected were: *Antrodia albida, Fomitopsis meliae, F. nivosa, F. palistris,* and *Gloeophyllum mexicanum*. Incidence of trees with decay was 63.7, 80.6, and 84.3 in the Ridge, Piedmont, and Coastal regions, respectively.

Disease severity ratings indicated that trees were affected mostly by decays of scaffold branches that were associated with improper stub-cut, pruning wounds. Based on tree age and health, wood decay is recognized as a distinct disorder and is associated with declining peach trees in commercial production in South Carolina.

---

[1]Research Plant Pathologist, Department of Plant Pathology, University of California, Davis, CA 95616

[2]Extension Plant Pathologist, Department of Plant Pathology, Clemson University, Clemson, SC 29634-0377

[3]Professor, Department of Plant Pathology, University of Arizona, Tucson, AZ 85721

BIOLOGY AND CONTROL OF WHITE PEACH SCALE

J.D. Dutcher[1]

ABSTRACT

Recent literature on the biology and control of white peach scale indicates many horticultural systems around the world are experiencing populations of white peach scale high enough to cause plant death and be uncontrollable with dormant oil sprays to infested limbs, trunks and vines. The scales seasonality is highly variable between hosts and between introduction sites and can have between two and six generations per season. The relatively simple natural enemy complex is often disrupted by oils and insecticides used for control of the scale and other insect pests. Unique bionomic characteristics of the scale and its parasites have been reported, yet entomologists cannot seem to agree on the best control procedure.

INTRODUCTION

The white peach scale, *Pseudaulacaspis pentagona* (Targioni-Tozzetti), is a worldwide problem on many ornamental plants and fruit trees. White peach scale is a factor in peach decline causing loss of peach trees when large populations are allowed to develop on the trunk and major scaffold limbs. Populations of the scale can become two or three layers thick as crawlers will often settle beneath an existing scale. The old scale provides a refuge from contact insecticide residues for the new scale. Therefore, the scales are difficult to control with contact insecticides during the summer.

BIOLOGY

White peach scale host plants include all non-coniferous plants (Ferris, 1937), and it is commonly found on 278 plants in Florida (Gossard 1902; Dekle, 1976). Although white peach scale is indigenous to Japan and China it has become a pest in Europe, Africa, North America and the Pacific Islands. It is the primary insect pest of non-astringent persimmons in Florida (Miller, 1989), passion fruit in Western Samoa (Liebregts and Sands, 1989), and purple grandilla in South Africa (Crause, 1990). The wide host range facilitates laboratory rearing as cultures are easily maintained on butternut squash or potato tubers (Crause, 1990). The life history varies between introduction sites. In temperate growing regions, the white peach scale overwinters as an inseminated female and eggs are laid soon after the first warm days of spring. In tropical growing areas, white peach scale continues to develop throughout the year. The optimum temperature range for population growth is 22-26 C. Each generation requires 42 to 56 days to complete at 25 C. Exceptionally warm temperatures in the winter favor outbreaks of the scale. The females produce an average of 230 eggs each generation and there are two to six generations per season. During the summer and fall generations, in Florida (Hamon, 1983), oviposition occurs 14-16 days after mating, eggs hatch three to four days after oviposition, crawlers settle onto new feeding sites within seven to nine days, first instar to adult requires about 20 days with females molting twice and males molting three times. In Italy, white peach scale had 2 complete generations and one partial generation a year (Garonna and Viggiani, 1988). In southern Taiwan, (Chen and Shih, 1984) six generations of white peach scale were observed on mulberry trees. Scales overwintered as inseminated females. There are 3 generations and a partial fourth generation in the Southeastern Atlantic Coastal Plain peach orchards (Dutcher et al., 1989; Nalepa and Meyer, 1990). The females release a pheromone to attract males, where release time coincides with eclosion of the males in the morning and there is no release of pheromone at night. When sexually mature females remain unmated for five days pheromone release begins earlier than in newly mature females (McLaughlin et al., 1990). In a laboratory bioassay, (McLaughlin, 1991) males from Florida differed from those in France in their responses to pheromone components indicating that the white peach scale populations may not be of the same species. White peach

[1]Department of Entomology, University of Georgia, Coastal Plain Experiment Station, Tifton, GA 31793-0748

scale eggs, crawlers and first instar nymphs occur in two colors when populations develop on most host plants. Eggs have many colors on a narrow set of host plants. Females develop from orange eggs and males develop from white eggs with orange eggs laid before white eggs (Bennett and Brown, 1958).

NATURAL ENEMIES

Parasites and predators have been identified and imported to various parts of the world to control white peach scale. Three species of hymenopteran parasites consistently collected from traps were the primary aphelinid parasites *Encarsia berlesei* and *Aphytis proclia* and the aphelinid hyperparasitoid *Marietta carnesi* (Nalepa and Meyer, 1990). Mortality is typically below 80% per season for all natural enemies combined and the high fecundity quickly produces more scale insects than the tree can withstand leading to limb dieback and possible tree death. The major natural enemies were the coccinellid predator *Lindorus lophanthae* and the aphelinid parasites *Aphytis proclia, Archenomus orientalis* and *Encarsia berlesei*. The life cycle of *A. orientalis*, an introduced parasite and the major parasite, was synchronized with that of the host. Field and laboratory studies (Viggianni and Garonna, 1986) found that mated, *A. orientalis* females oviposited mainly in the 2nd instar nymphs of the scale and matured as the scale developed for 45 days, emerging from the adult scale. An unusual type of development was found in the haploid male parasite. Unmated parasitoid females oviposited haploid eggs (males) into hosts parasitized by mated females of their own species. Development of the haploids was arrested at the first instar until the female parasitoid larva was mature. The haploid larvae then completed development on the full grown female larva. *A. orientalis* had 3 generations a year, in the field, overwintering as an adult female. In southern Taiwan (Chen and Shih, 1984), eight hymenopterous parasites regulated the scale population though populations of scales increase during the summer and fall.

CONTROL

Chemical control with oils or insecticides is most effective when the materials are applied to the entire orchard where trees or tree limbs with uncontrollable populations are removed from the orchard. They are usually controlled by two applications of oil to infested areas of the tree two and four weeks before budbreak. High populations are difficult to control with any means. Oil sprays were most effective and beneficial to the natural enemies when applied against immature, emdedded, scale nymphs in the fall. Dormant oils before budbreak cause significant reductions in the emergence of the overwintering parasites of white peach scale, killing 25-75% of the hymenopterous parasites after the first spray. Fortunately, parasites will continue to increase in sprayed trees (Meyer and Nalepa, 1991). Control recommendations vary from application of chlorpyrifos against the first instar scales of the first spring generation and avoiding insecticide applications to the late season populations (Montermini, 1985) to spraying the crawler stage (Hamon, 1983). Resurgence of scales following application of broad spectrum contact insecticides for fruit pests is common (Montermini, 1985; Dutcher et al., 1989). Fruit pest control in southern Georgia is a series of weekly cover sprays of phosmet or encapsulated methyl parathion between fruit thinning and harvest. These sprays can reduce predators and hymenopterous parasites of the white peach scale and lead to resurgence of scale populations on the tree. Conservation of white peach scale natural enemies is an important consideration in the choice of insecticides against fruit scarring insects.

RECENT RESULTS

Davidson et al. (1983) indicated that populations of *P. pentagona* are actually populations of *P. prunicula*. I have determined through examination of over 5,000 specimens that the populations in south Georgia orchards are *P. pentagona*. I have determined through season long sampling of scales on peach that white peach scale in southern Georgia has

three male flight periods, females lay eggs in three peaks during the summer, and crawlers hatch all season long at varying rates. I also found that trees appear to be reinfested by crawlers from adjacent trees. In control trials, treated trees next to untreated trees are reinfested at a faster rate than trees next to treated trees. One important factor in the bionomics of white peach scale in southern Georgia that increases its status as a pest is: The overwintering females produce eggs and crawlers hatch during the warm days of the winter. Fortunately, the hymenopterous parasites are also actively emerging from field populations of the scale during the winter.

LITERATURE CITED

Bennett, F.D. and S.W. Brown. 1958. Life history and sex determination in Diaspine scale, *Pseudaulacaspis pentagona* (Targ.) (Coccoidea). Can. Entomol. 110:317-324.

Chen, C.T. and C.I.T. Shih. 1984. Seasonal population abundance of white peach scale, *Pseudaulacaspis pentagona* (Targ.) and its parasites. J. Agr. For. 33:57-63.

Crause, C. 1990. The white peach scale, *Pseudaulacaspis pentagona* (Targioni-Tozzetti) (Homoptera:Diaspidae), a pest of economic importance on grandilla. Acta Hort. 275:655-662.

Dekle, G.W. 1976. Arthropods of Florida and neighboring land areas: Florida armored scale insects. 3. Gainesville, FL: FL Dept. Agr. and Consumer Serv. 138.

Davidson, J.A., D.R. Miller and S. Nakahara. 1983. The white peach scale, *Pseudaulacaspis pentagona* (Targioni-Tozzetti) (Homoptera: Diaspididae): Evidence that current concepts include two species. Proc. Entomol. Soc. Washington 85:753-761.

Dutcher, J.D., M.J. Townsend and J.R. Rowe. 1989. White peach scale field biology in southern Georgia. Proc. SE Fruit Workers Conf. 7 Pp.

Ferris, G.F. 1937. Atlas of the scale insects of North America. Series 1. Stanford Univ. Press, CA. 285 Pp.

Garonna, A.P. and G. Viggiani. 1988. Observations on the white peach scale (*Pseudaulacaspis pentagona* -Targ. Tozz.-) and its natural enemies in Campania. Annali della Facolta di Scienze Agrar. della Univ. degli Studi di Napoli, Portici, IV. 22:1-10.

Gossard, H.A. 1902. White peach scale (*Diaspis pentagona*). FL Agr. Exp. Sta. Bul. 61:492-498.

Hamon, A.B. 1983. White peach scale, *Pseudaulacaspis pentagona* (Targ.-Tozz.) (Homoptera: Coccoidea: Diaspididae). Entomol. Circ., Div. Plant Ind. FL Dept. Agr. Consumer Serv. No. 253, 2 Pp.

Liebregts, W.J.M.M. and D.P.A. Sands. 1989. Population studies and biological control of *Pseudaulacaspis pentagona* (Targioni-Tozzetti) (Hemiptera:Diaspididae) on passion fruit in Western Samoa. Bul. Entomol. Res. 79:163-171.

McLaughlin, J.R. 1991. Behavioral response of male white peach scale to the sex pheromone, (R,Z)-3,9,-dimethyl-6-isopropenyl-3,9-decadien-1-o l propionate and corresponding alcohol. J. Chem. Ecol. 16:749-756.

McLaughlin, J.R., R.R. Heath, T.R. Ashley. 1990. Periodicity of pheromone release from female white peach scale. Physiol. Entomol. 15:193-197.

Meyer, J.R. and C.A. Nalepa. 1991. Effect of dormant oil treatment on white peach scale (Homoptera: Diaspidae) and its overwintering parasite complex. J. Entomol. Sci. 26:27-32.

Miller, E.P. 1989. Performance of non-astringent persimmons (*Diospyros kaki* L.) in Florida. Proc. FL State Hort. Soc. 102:199-202.

Montermini, A. 1985. Control of the white peach scale. Informatore Fitopatologico. 35: 10-16.

Nalepa, C.A. and J.R. Meyer. 1990. The seasonal history of the white peach scale (Homoptera: Diaspidae) and its Hymenopteran natural enemies in North Carolina. J. Entomol. Sci. 25:303-310.

Viggiani, G. and A.P. Garonna. 1986. Preliminary observations of *Archenomus orientalis* Silvestri (Hymenoptera: Aphelinidae), parasite of white peach scale (*Pseudaulacaspis pentagona* (Targioni-Tozzetti). Bollettino del Laboratorio di Entomologia Agraria "Filippo Silvestri", Italy 43:223-227.

THRIPS DAMAGE AND CONTROL ON STONEFRUIT IN NEW ZEALAND

D.A.J. Teulon[1]

Thrips have been associated with economic damage to stonefruit throughout the world including Australia (Zeck and Noble, 1932; Allman, 1948), California (Moulton, 1909; Foster and Jones, 1915; Weldon, 1921; Bailey, 1938; Black et al., 1963; La Rue et al., 1972), France (Bournier and Blache, 1956; Bournier, 1970), Georgia (Yonce et al., 1990 a, b), Greece (Kourmadas et al., 1982), Italy (Pollini and Giunchi, 1979; Cravedi et al., 1983; Cravedi and Molinari, 1984) and New Zealand (Teulon and Penman, 1987, 1988; McLaren, 1992). This paper gives a brief overview of the stonefruit industry in New Zealand, and examines the thrips problems associated with stonefruit during flowering and at harvest.

The New Zealand Stonefruit Industry. The stonefruit industry in New Zealand is small compared to the kiwifruit and pipfruit (pomefruit) industries. In 1991 export earnings from apricots, cherries, nectarines, peaches and plums was NZ$12.3 million (Anon., 1992). Nectarines account for 52% of the volume of stonefruit exports followed by peaches, apricots, and cherries with Australia the main export market (Anon., 1992). Traditionally nectarine and peach production was aimed at the local market (Wilton, 1984) but since 1980 there has been greater emphasis on planting varieties for the export market (Shepard, 1984).

To compete on export markets New Zealand stonefruit must be of premium quality, free of insect damage and contamination, and with minimum pesticide residue (Tomkins, 1985). 'Acceptable quality levels' for fruit destined for export markets are established by the New Zealand Summerfruit Industry based on 'gazetted' Government regulations (Fruit & Vegetable Regulations 1975, Plant Act 1970). Orchard pest control relies heavily on the use of chemical sprays which are considered necessary for successful stonefruit production (Penman, 1984; Jackson, 1986). Recommended spray schedules were published yearly by the Ministry of Agriculture.

The main insect pests for peaches and nectarines in New Zealand are listed in Table 1. 'Key' pests are those requiring continuous control in order to grow a crop which gives maximum returns. The tolerance of damage from these pests is very low, effectively zero for export quality fruit. 'Occasional' pests are those requiring only infrequent control. Some pests are 'secondarily induced' because in the absence of controls for key pests they may be controlled by natural enemies. Economically important diseases include: Silverleaf [*Chondrostereum purpureum* (Pers. ex Fr.) Pouz.], blast (*Pseudomonas syringae* van Hall), brown rot [*Monilinia fructicola* (Wint.) Honey], leaf-curl [*Taphrina deformans* (Berk.) Tul.] and bacterial spot [*Xanthomonas pruni* (Erw. Smith) Dow].

The New Zealand Flower Thrips. A key pest of stonefruit is the polyphagous flower inhabiting New Zealand flower thrips (NZFT), *Thrips obscuratus* (Crawford) (Thysanoptera: Thripidae), which is considered to be endemic to New Zealand but has now colonized many introduced plants including deciduous fruit trees (Teulon and Penman, 1990). Adult NZFT lay eggs in the flowers of host plants where the two larval stages feed and develop. When mature, 2nd instar larvae fall to the ground where pupation occurs (Teulon, 1988). High fecundity, low temperature thresholds for oviposition and development, and short generation time (Teulon and Penman, 1991) ensure that the small highly mobile (adult) thrips can fully exploit their ephemeral flower habitats in spring. Adults and larvae of NZFT are found throughout the year where host plant flowers are available, such as in Canterbury (Teulon, 1988). There is no reproductive diapause so continuous generations can occur. Inside stonefruit orchards, Teulon (1988) found that thrips numbers, as measured by water trap catches, were lowest in winter (June - August) but increased gradually during spring (September,

[1]Department of Entomology, Penn State University, University Park, PA 16802

October) and early summer (November, December). Numbers peaked in midsummer (mid January) but declined suddenly in late January. Numbers remained moderate to low throughout late summer (February, March) and autumn (April, May) (Teulon, 1988). NZFT appear to be primarily orchard invaders as few thrips have been found emerging from the soil within orchards (Teulon, 1988). Although several predators (Mound and Walker, 1982) and one internal nematode parasite (Teulon, 1988) are known to occur for NZFT, natural enemies do not appear to have a significant impact on population size at least in stonefruit orchards.

Increased pest status of NZFT coincided with the rapid expansion of the New Zealand horticultural industry during the 1970's and early 1980's and it is now the most important thrips pest on stonefruit in New Zealand during flowering and at harvest (Teulon and Penman, 1987, 1988; McLaren, 1992). It has been implicated in the mechanical transfer of the fungal pathogen, *Monilinia fructicola*, to stonefruit flowers and fruit (Ellis et al., 1988) and is also a contaminant of several other horticultural exports (Mound and Walker, 1982).

Thrips On Nectarine During Flowering. Adult NZFT is the main thrips species inhabiting stonefruit flowers in New Zealand (Teulon, 1988; McLaren, 1992). The adults invade nectarine and peach flowers from the pink stage and lay eggs until petal fall. Adults and larvae feed on the succulent tissues of the flower until shuck fall (Teulon, 1988). In New Zealand, feeding damage by thrips on the ovaries and small fruits is largely restricted to nectarine and results in irregularly shaped blocks of russet, sometimes associated with fine scar lines, and in severe cases, distortion of fruit. Damage to nectarine by thrips was first identified in Central Otago (McLaren, 1992) where export packout from russetting could be reduced significantly. Since NZFT flies throughout spring, and very few NZFT are required to cause economic damage during flowering (Teulon and Penman, 1987), prophylactic control is needed for thrips on export crops every season.

In 1987 recommended spray programs for thrips control at flowering in New Zealand included insecticide applications at bud movement (lindane and oil) and petal fall (chlorpyrifos) followed by two further sprays (azinphosmethyl) at ten day intervals. Insecticides were not applied to the trees during bloom to minimize bee poisoning even though there is significant thrips activity at this time (Teulon and Penman, 1987; McLaren, 1992). McLaren (1992) stated that damage was only caused by adult female thrips but larvae were also considered to be important by Teulon and Penman (1987) and other researchers (Bailey, 1938; LaRue et al., 1972; Bournier, 1983; Cravedi and Molinari, 1984).

Protection of nectarines from thrips infestation and damage during flowering was investigated by Teulon and Penman (1987) using the insecticides fluvalinate or phosalone applied at full bloom as supplements to the recommended spray program. Both insecticides are considered to have minimum hazard to honey bees (Johansen et al., 1983). Thrips numbers were reduced on trees treated at full bloom with both insecticides and export packout, based on russett only, was 10% higher on the trees treated at full bloom compared to those treated only with the recommended spray program. Fluvalinate became registered for thrips control on nectarine during flowering.

Thrips On Peach During Harvest. Thrips are found in stonefruit orchards during harvest (December - March) where adult female thrips feed and oviposit on the fruit and some larvae hatch before the fruit is picked. Thrips adults and larvae taken from ripe nectarines and peaches by Teulon (1988) were almost all NZFT even though other thrips species were collected from water traps within the orchard. Almost all adults were female. Adults, eggs and larvae were most common on ripe fruit, although they were found in low numbers on unsprayed unripened fruit up to three weeks before harvest (Teulon, 1988). Thrips numbers were higher on ripe peaches than nectarines. The seasonal variation of thrips numbers on ripe stonefruit reflected thrips flight patterns rather than varietal differences. Most thrips adults were found on

fruit varieties that matured during the period of maximum thrips flight in December and January (Teulon, 1988). Feeding damage by NZFT on mature fruit is minor unless infestations are severe. The main economic problem is due to contamination of export fruit by thrips adults, eggs and larvae.

Control of NZFT at harvest for export markets is difficult. Continual pesticide coverage is needed to prevent NZFT infestion of fruit because large numbers of thrips enter the orchard during harvest from breeding hosts outside. Pesticide residues on fruit need to be low for market acceptance, but they need to be applied close to harvest because thrips are increasingly found on peaches as they mature. To reduce the residue levels on fruit, pesticides with a short residual life have to be used but these soon lose their effectiveness and reinfestation can occur.

Preharvest control strategies for thrips on fruit in 1988 relied on applications of the short residual action carbamate insecticide, carbaryl, 14 days prior to harvest, immediately prior to harvest and at 7 day intervals during harvest. Field treatments do not give complete control of adult and larval thrips on peaches and nectarines, possibly because the short persistence of carbaryl allows thrips infestation between treatments (Teulon and Penman, 1988; McLaren, 1989). Reinfestation can be a particular problem where several fruit varieties occur in the same block because staggered ripening dates compromise the ability to apply insecticides at appropriate times.

Teulon and Penman (1988) reported the use of fluvalinate at low application rates for preharvest control of thrips on peach fruit. Low application rates of fluvalinate (5% to 20% of recommended field rates) reduced thrips infestation on two peach varieties and some treatments were more effective than the recommended spray program. Teulon and Penman (1988) stated that successful control with fluvalinate at low application rates and earlier evidence of repellency with mites (Penman et al., 1986) suggested that repellancy, rather than direct toxicity, was important for reducing thrips infestation on peach fruit. Given appropriate residue clearances, fluvalinate may provide a low rate, single application strategy for preharvest control of NZFT on peach.

Post-harvest disinfestation. Field treatments do not always give adequate control of adult and larval thrips on peach and nectarine. If live pests are intercepted on arrival in Australia the fruit is fumigated with methyl bromide which results in reduced fruit quality, and delays of up to several weeks (Birtles et al., 1991). Therefore various methods of postharvest treatment have been attempted. These include the placement of dichlorvos strips in the packing case (McLaren, 1982), physical removal of thrips by blasting with air (McLaren, 1983), dipping into fungicides, wetting agents or insecticides (McLaren and Dale, 1989) and the use of controlled temperatures (McLaren, 1989).

Summary. The low economic injury levels and inadequacy of other control tactics (e.g., biological, cultural) has led to a reliance on chemical control for thrips on stonefruit in New Zealand. The judicious use of insecticides for NZFT control during flowering provides fruit that is acceptable for local and export markets. However the control of NZFT at harvest for export markets is a more intractable problem and postharvest disinfestation will likely be a key to future control.

ACKNOWLEDGEMENTS

This manuscript was improved with comments from E.G. Rajotte and E. A. Cameron (Department of Entomology, Penn State University).

LITERATURE CITED

Allman, S.L. 1948. Skin blemish of nectarines caused by plague thrips. The Agr. Gaz. of New South Wales 59:423-426.

Anonymous. 1992. New Zealand Official Year Book. 95th edition. New Zealand Dept. of Stat. [Te Tari Tatau].

Bailey, S.F. 1938. Thrips of economic importance in California. CA Agr. Expt. Sta., Circ. No. 346. 77 Pp.

Birtles, D.B., B.C. Waddles and J.H. Maindonald. 1991. High temperature disinfestation of nectarines: Lightbrown apple moth larvae. Proc. 44th New Zealand Weed and Pest Control Conf. Pp. 61-65.

Black, J.H., C.S. Davis, V.E. Burton and K.W. Hench. 1963. Thrips control on nectarines. CA Agr. 17(3):6-7.

Bournier, A. 1970. Degats de thrips sur nectarines. Phytoma 22:26-29.

Bournier, A. 1983. Les thrips - biologie, importance agronomique. Institut National de la Reserche Agronomique, Paris. 128 Pp.

Bournier, A. and M. Blache. 1956. Thysanopteres nuisibles aux pechers. Revue de zoologie agricole et appliqee 55:1-8.

Cravedi, P. and F. Molinari. 1984. Tisanotteri dannosi alle nettarine. Informatore fitopatologica 34(10):12-16.

Cravedi, P., F. Molinari and G. Spada. 1983. ontrollo del *Taeniothrips meriodonalis* Priesn. (Thysanoptera: Terebrantia: Thripidae) dannoso alle nettarine. Redia 66:37-46.

Ellis, E.C., D.R. Penman and R.E. Gaunt. 1988. Thrips as potential vectors of brown rot of stonefruit in New Zealand. Proc. 41st New Zealand Weed and Pest Control Conf. Pp. 286-287.

Ferro, D.N., A.D. Lowe, R.G. Ordish, K.G. Somerfield and J.C. Watt. 1977. Standard names for common insects of New Zealand. Bul. Entomol. Soc. New Zealand 4:1-42.

Foster, S.W. and P.R. Jones. 1915. The life history and habits of the pear thrips in California. U.S. Dept. Agr. Bul. 173:1-52.

Helson, G.A.H. 1952. Insect pests affecting horticultural crops and plants in New Zealand. Plant Quarantine Serv., Circ. No. 2:1-32.

Jackson, D.I. 1986. Stonefruit, Pp. 168-183. In: D.I. Jackson (ed.) Temperate and Subtropical Fruit Production. Butterworths, Wellington.

Johansen, C.A., D.F. Mayer, J.D. Eves and C.W. Kious. 1983. Pesticides and bees. Env. Entomol. 12:1513-1518.

Kemp, W.S. 1971. Growing peaches and nectarines. Insect Pests. New Zealand J. Agr. 123(6):77-79.

Kourmadas, A.L., T. Zestas and L.C. Argyriou. 1982. Timing of spraying for control of thrips in nectarine trees. Annales de l'Institut Phytopathologique Benaki 13:120-129.

LaRue, J.H., J.E. Dibble and G. Obenauf. 1972. Thrips in nectarines. The Blue Anchor (spring): 21-25.

Lovett, A.L. 1921. The pear thrips. Oregon Agr. College Expt. Sta. 3rd Crop Pest and Hort. Rep. Pp. 95-102.

McLaren, G.F. 1982-1983. Annual reports - Entomology Division, New Zealand Dept. of Sci. and Ind. Res. (1982) 1980-81, (1983) 1981-82.

McLaren, G.F. 1989. Development of a high temperature disinfestation method for New Zealand flower thrips *Thrips obscuratus* (Crawford) on peaches and nectarines. Entomol. Div., New Zealand Dept. Sci. and Ind. Res., Auckland.

McLaren, G.F. 1992. Thrips on nectarines in the spring. Proc. 45th New Zealand Weed and Pest Control Conf. Pp. 11-115.

McLaren, G.F. and J.R. Dale. 1989. Control of thrips on stonefruit at harvest time. Entomol. Division Report Series No. 8, New Zealand Dept. of Sci. and Ind. Res., Auckland. 40 Pp.

Moulton, D. 1909. The pear thrips. U.S. Dept. Agr. Bur. Entomol. Bul. 68(I):1-16. (Revised)

Mound, L.A. and A.K. Walker. 1982. Terebrantia (Insecta: Thysanoptera). Fauna of New Zealand No. 1. 113 Pp.

Penman, D.R. 1976. Deciduous tree fruit pests, Pp. 28-43. In: D.N. Ferro (ed.) New Zealand Insect Pests. Lincoln Univ. College of Agr. 311 Pp.

Penman, D.R. 1984. Deciduous tree fruit pests, Pp. 33-50. In: R.R. Scott (ed.) New Zealand Pest and Beneficial Insects. Lincoln Univ. College of Agr. 373 Pp.

Penman, D.R., R.B. Chapman and M.H. Bowie. 1986. Direct toxicity and repellent activity of pyrethroids against *Tetranychus urticae* (Acari: Tetranychidae). J. Econ. Entomol. 79:1183-1187.

Pollini, A. and P. Giunchi. 1979. *Taeniothrips meridionalis* Priesne *Thrips major* Uzel: due Tisanotteri Terebranti dannosi alle cultivar di nettarine. La difesa piante 4:219-230.

Shepard, S. 1984. Market increase in planting of export stonefruit varieties. Hort. News 6(2):10.

Teulon, D.A.J. 1988. Pest management of the New Zealand flower thrips *Thrips obscuratus* (Crawford) (Thysanoptera: Thripidae) on stonefruit in Canterbury, New Zealand. Ph.D. thesis, Lincoln College, Univ. of Canterbury, New Zealand. 221 Pp. (& addendum).

Teulon, D.A.J. and D.R. Penman. 1987. Thrips control on stonefruit at flowering in Canterbury. Proc. 40th New Zealand Weed and Pest Control Conf. Pp. 153-156.

Teulon, D.A.J. and D.R. Penman. 1988. Thrips control on stonefruit at harvest with fluvalinate. Proc. 41st New Zealand Weed and Pest Control Conf. Pp. 262-266.

Teulon, D.A.J. and D.R. Penman. 1990. Host records for the New Zealand flower thrips [*Thrips obscuratus* (Crawford) Thysanoptera: Thripidae]. The New Zealand Entomol. 13:46-51.

Teulon, D.A.J. and D.R. Penman. 1991. Effects of temperature and diet on oviposition rate and development time of the New Zealand flower thrips (*Thrips obscuratus*). Entomologia Experimentalis Et Applicata 60(2):143-155.

Tomkins, A.R. 1985. Insect control: Peaches and nectarines. Southern Hort. 22:24.

Weldon, G.P. 1921. Thrips injury to peaches in southern California. J. Econ. Entomol. 14:424-428.

Wilton, W.J.W. 1984. Stonefruit industry statistics and background. Aglink HPP 249. Ministry of Agr. and Fisheries, New Zealand.

Yonce, C.E., J.A. Payne, R.J. Beshear and D.L. Horton. 1990a. Thrips (Thysanoptera: Thripidae) associated with unsprayed and sprayed peaches in Georgia. J. Econ. Entomol. 83:511-518.

Yonce, C.E., R.J. Beshear, J.A. Payne and D.L. Horton. 1990b. Population distribution of flower thrips (Thysanoptera: Thripidae) in nectarine and their relative association with injury to fruit in the southeastern United States. J. Entomol. Sci. 25:427-438.

Zeck, E.H. and N.S. Noble. 1932. Thrips. Experiments for the control of *Thrips imaginis* Bagnall. Agr. Gaz. of New South Wales 43:231-236.

Table 1. Classification of New Zealand stonefruit pests.

Pest Status		
Key	Occasional	Secondary Induced
Lightbrown apple moth	Earwigs	San Jose scale
Brownheaded leafroller	Mealybugs	Oystershell scale
Greenheaded leafroller	Grass grub	European red mite
Oriental fruit moth	Cherryslug	Two spotted spider mite
N.Z. flower thrips	Green peach aphid	

Plant Part Attacked		
Fruit	Foliage	Branch/Shoot/Root
Leafrollers	Leafrollers	Scales
N.Z. flower thrips	Mites	
Oriental fruit moth	Mealbugs	
Earwigs	Green peach aphid	
Green peach aphid	Cherryslug	
	Grass grub	

Damage Type		
Chewing	Sucking	Cosmetic
Leafrollers	N.Z. flower thrips	N.Z. flower thrips
Oriental fruit moth	Mites	Mealybugs
Grass grub	Scales	Scales
Cherryslug	Mealybugs	
	Green peach aphid	

List compiled from Helson (1952), Kemp (1971), Penman (1976, 1984), and Tomkins (1985).
Common names according to Ferro et al. (1977)

POPULATION DISTRIBUTION AND CONTROL EFFICACY FOR FLOWER THRIPS ASSOCIATED WITH PEACH AND NECTARINE IN SOUTHERN ORCHARDS

C.E. Yonce[1]

ABSTRACT

The flower thrips, *Frankliniella tritici* (Fitch), the western flower thrips, *Frankliniella occidentalis* (Pergande), and the soybean thrips, *Neohydatothrips variabilis* (Beach), were the most abundant thrips species recovered from the orchard. Each of the three species was abundant during different years. The western flower thrips proved to be most injurious in causing russeting of fruit surfaces. The soybean thrips contributed little or no damage to fruit. Sprays applied at 15% bloom and 10% petal fall were most effective for control of russeting injury caused by flower thrips. Russeting injury to fruit was light and % marketable fruit was high with low western flower thrips populations. Lannate was as effective as Carzol (standard) under light thrips pressure, but is not currently labeled on nectarine.

INTRODUCTION

Development of new nectarine cultivars for the southeastern United States has stimulated a renewed interest in commercial nectarine production. Although nectarines are similar to peach, their glabrous surface, distinctive color, flavor, and aroma distinguish them from peach (Okie et al., 1985). Generally the same complex of arthropods and diseases attack both peach and nectarine, but nectarine fruit are apparently more susceptible to superficial surface injury. Major markets expect nectarines to be nearly flawless. Pest management strategies for arthropod pests of peaches have been static for several years. Little information was available on thrips and their pest potential to nectarines in southern United States. Researchers in California (USA), France, Italy, and Greece have emphasized the importance of controlling thrips in commercial nectarine orchards (LaRue et al., 1972; Kourmadas et al., 1982; Cravedi et al., 1983; Cravedi and Molinari, 1984).

Population distribution and control studies of thrips on nectarine and peach in southern United States were lacking. This paper reports on the adult and larval distribution of three abundant thrips species collected from nectarine trees during a three-year study and control strategies during 1988, 1989, and 1990.

MATERIALS AND METHODS

The population distribution study was conducted in a small planting using an advanced nectarine cultivar selection from the breeding program at the Southeastern Fruit and Tree Nut Research Laboratory, Byron, Georgia. Ten random trees were sampled each week from pink bud until after harvest for the three-year study. Technical piperonyl butoxide, 60% ai plus 6% ai pyrethrins was used as a quick knock-down insecticide at the rate if 1.3 ml/liter of water (Yonce et al., 1990). A modified version of a method designed for sampling pecan arthropods was used throughout the study (Tedders, 1983). Thrips were identified by methods described by Moulton (1948), Stannard (1968), Allen and Broadbent (1986), and Sakimura (1986). Voucher specimens were sent to S. Nakahara (USDA-Insect Identification Laboratory, Beltsville, MD 20705) and returned.

Control studies were done at the Byron Laboratory. Carzol 92SP (0.5 lb ai/A) was used during 1988 (Table 1), while Carzol (same rate) and Lannate 1.8 WLS (1.0 lb ai/A) were used during 1989 (Table 2). Again in 1990, Carzol and Lannate were tested in commercial orchards in Peach and Brooks counties, Georgia (Table 3).

RESULTS AND DISCUSSION

Sampling in nectarines during 1986, 1987, and 1988 yielded eighteen different species of thrips of which seventeen species were in the suborder Terebrantia and only one species in the suborder Tubulifera. Three species were captured in enough abundance to warrant attention.

[1]Research Entomologist, USDA-ARS, Southeastern Fruit and Tree Nut Research Laboratory, P.O. Box 87, Byron, GA 31008

In 1986, russeting damage was relatively light and the flower thrips, *Frankliniella tritici* (Fitch), was most abundant (Fig. 1). In 1987, the soybean thrips, *Neohydatothrips variablis* Beach was most abundant and russeting damage was extremely light. Soybean thrips were determined to contribute little or no russeting damage to nectarine fruit (Fig. 2). In 1988, the western flower thrips, *F. occidentalis* (Pergande), was most abundant and russeting damage was excessively high (Fig. 3). It was concluded from the study that the flower thrips contributes light to moderate russeting damage to fruit while the western flower thrips contributes greatly and causes severe russeting and sometimes severe silvering damage to nectarine fruit. The soybean thrips is not a contributor to russeting fruit damage. Lack of or below normal rainfall during early season (pink bud-petal fall) appears to provide ideal conditions for the western flower thrips' survival.

In 1988, control strategy directed at bloom and early fruit development was more effective for russeting control than all treatments applied later (Table 1).

In 1989, with more frequent applications during bloom, two applications made at popcorn pink and 10% petal fall were most effective for control using Carzol, while two applications (true pink and 90% petal fall) were most effective using Lannate (Table 2).

In 1990, in commercial nectarine orchards in Peach and Brooks counties, two applications made at 15% bloom and 10% petal fall were most effective. Thrips larval counts were not reduced until after the second application (Table 4). Damage assessment for russeting at harvest revealed that there were no significant differences among treatments (including check) in Brooks County, Georgia. Peach County, Georgia data indicates that no differences existed among insecticide treatments, but revealed a higher ($P \leq 0.05$) percentage of marketable fruit than the check (Table 5).

It's noteworthy to mention that the flower thrips was in greater abundance than the more damaging western flower thrips in both test sites. Realistically, it was not enough of a damaging thrips pressure season to further substantiate data comparing effectiveness of Lannate vs the standard Carzol. The data suggests that flower thrips can indeed be controlled with two insecticide applications directed at 15% bloom and 10% petal fall. Later applications would be too late, because larvae are already present and feeding during the blooming period before fruit are visible.

LITERATURE CITED

Allen, W.R. and A.B. Broadbent. 1986. Transmission of tomato spotted wilt virus in Ontario greenhouses by *Frankliniella occidentalis*. Can. J. Plant Pathol. 8:33-38.

Cravedi, P. and F. Molinarai. 1984. Tisanottera dannosi alle nettarince. (In Italian) Informatore Fitopathologica 34:12-16.

Cravedi, P., F. Molinarai and G. Spada. 1983. Controllo del Taeniothrips meridonalis Preisn. (Thysanoptera, Terebrantia, Thripidae) dannoso alle nettarine. (In Italian) Redia 66:37-46.

Grizzle, J. E., C. F. Starmer and G. G. Koch. 1969. Analysis of categorical data by linear models. Biometrics 25:489-504.

Kourmadas, A.L., T. Zestas and L.C. Argyriou. 1982. Timing of spraying for control of thrips in nectarine trees. Annu. Inst. Phytopath. Benaki (N.S.) 13:120-129.

LaRue, J.H., J.E. Dibble and G. Obenauf. 1972. Thrips in nectarines. The Blue Anchor (spring) 21-25.

Moulton, D. 1948. The genus *Frankliniella* Karny, with keys for the determination of species (Thysanoptera). Rev. Entomol. 19:Fasc. 1-2.

Okie, W.R., D.W. Ramming and R. Scorza. 1985. Peach, nectarine, and other stone fruit breeding by the USDA in the last two decades. HortScience 20:633-641.

Sakimura, K. 1986. Thrips in and around the coconut plantations in Jamaica, with a few taxonomical notes (Thysanoptera). FL Entomol. 69:348-363.

Stannard, L. J. 1968. The Thrips, or Thysanoptera of Illinois. Bul. IL State Natl. Hist. Survey 29:215-552.

Tedders, W. L. 1983. Improved and new methodology for sampling mature pecan trees for arthropods. J. Ga. Entomol. Soc. 18: 549-555.

Yonce, C. E., J. A. Payne, R. J. Beshear and D.L. Horton. 1990. Thrips associated with unsprayed and sprayed peaches in Georgia (Thysanoptera: Thripidae). J. Econ. Entomol. 83:511-518.

Table 1. Treatments, spraying sequence and proportion of blemished fruit using a contingency table analysis using weighted least squares (Grizzle et al., 1969) on the distribution of injury to fruit. 1988.

Date of Application	Phenological Stage	Treatments (Carzol)[z] A	B	C	D	E (ck)
24 March	75% Bloom				X	
5 April	60% Petal fall			X	X	
13 April	Shuck off	X		X	X	
28 April	Progressive	X				
5 May	/	X	X	X		
12 May	fruit	X	X	X		
18 May	/	X	X			
31 May	size and	X	X			
9 June	/	X	X			
16 June	development	X				
28 June	Harvest					

Treatment (Carzol)	Proportion of blemished fruit None	Slight	Med/Hvy
D	.71	.20	.09
C	.68	.20	.12
A	.61	.24	.15
E (ck)	.59	.22	.19
B	.59	.26	.15

[z]Carzol 92 SP (0.5 lb ai/A).

Table 2. Treatments, spraying sequence and proportion of blemished fruit using a contingency table analysis using weighted least squares (Grizzle et al., 1969) on the distribution of injury to fruit. 1989.

Date of application	Phenological stage	Treatments (Carzol and Lannate)[z] A	B	C	D	E	F (ck)
10 March	true pink	X	X		X	X	
12 March	popcorn pink	X		X			
15 March	20% bloom	X	X			X	
24 March	10% petal fall	X		X			
31 March	90% petal fall	X			X	X	
7 April	shuck split	X					

Treatment (Carzol)	Proportion of blemished fruit None	Slight	Med/Hvy
C	.88	.09	.03
A	.87	.11	.02
E	.86	.11	.03
B	.83	.15	.02
D	.79	.18	.03
F(ck)	.46	.35	.19

Treatment (Lannate)	Proportion of blemished fruit None	Slight	Med/Hvy
D	.89	.09	.02
A	.85	.13	.02
C	.85	.13	.02
B	.84	.13	.03
E	.83	.15	.02
F	.46	.35	.19

[z]Carzol 92 SP (0.5 lb ai/A) and Lannate 1.8 WLS (1.0 lb ai/A).

Table 3. Chemical treatment regimen; Brooks and Peach Counties, Georgia, 1990.

Insecticide/Formulation/Rate	Popcorn Pink	15% Bloom	10% Petal fall
A Carzol 92SP 0.5 lb.ai/A	X	-	X
B Carzol 92SP 0.5 lb.ai/A	-	X	X
C Carzol 92SP 0.5 lb.ai/A	-	-	X
AA Lannate 90S 0.75 lb.ai/A	X	-	X
BB Lannate 90S 0.75 lb.ai/A	-	X	X
CC Lannate 90S 0.75 lb.ai/A	-	-	X
Check (untreated)	-	-	-

Table 4. Thrips larval counts befor, during, and after treatment. Brooks County, Georgia 1990.

Sample Date	Insecticides (mean larvae)[Z]			Phenological Stage
	Carzol	Lannate	Untreated	
2/7/90	0	0	0.8	5% popcorn pink
2/12/90	1.5	41.0	5.0	15% bloom
2/13/90	TREATED			15% bloom
2/15/90	1.0	44.8	49.0	10% petal fall
2/16/90	TREATED			10% petal fall
2/21/90	9.0	19.5	163.0	50% petal fall
2/28/90	13.3	21.5	86.8	90% petal fall

[Z]Data taken from B and BB treatments (Table 3).

Table 5. Thrips russeting damage on fruit at harvest in Brooks and Peach counties, 1990.

Insecticide	% Marketable fruit[Z]	
	Brooks County	Peach County
Carzol A	99.5 a	97.3 a
B	99.5 a	97.0 a
C	99.3 ab	97.7 a
Lannate AA	99.0 ab	98.0 a
BB	99.3 ab	98.0 a
CC	97.0 b	98.3 a
Untreated	97.5 ab	90.3 b

[Z]Means followed by the same letter in a column are non-signifcant according to DMRT ($P \leq 0.05$).

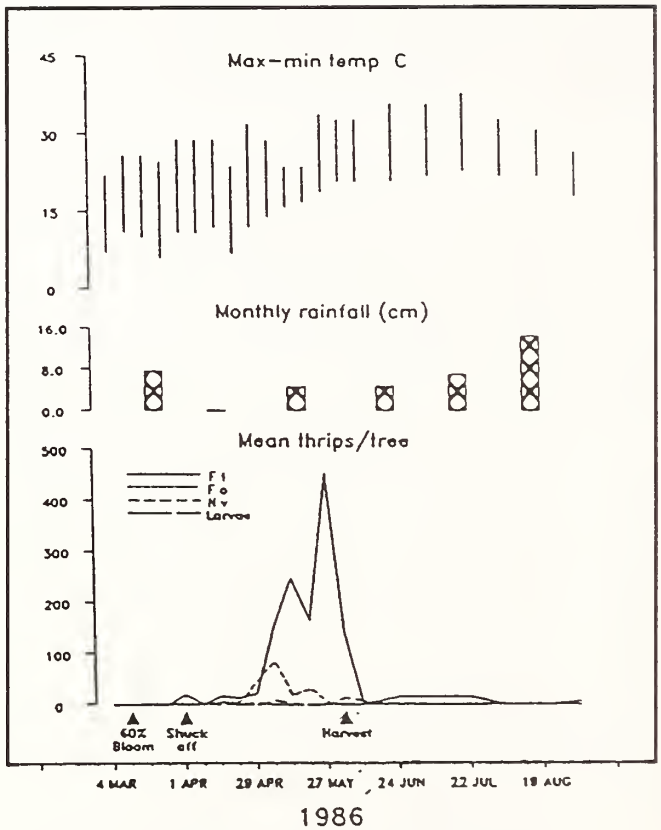


Figure 1. Seasonal distribution of adults of the flower thrips (Ft), the western flower thrips (Fo), the soybean thrips (Nv), and undetermined thrips larvae in unsprayed nectarines, 1986.

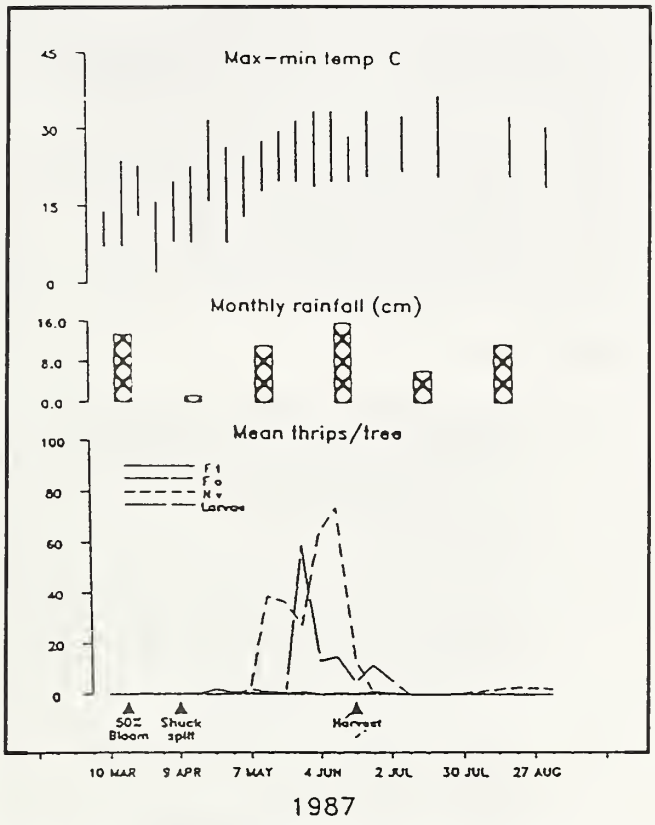


Figure 2. Seasonal distribution of adults of the flower thrips (Ft), the western flower thrips (Fo), the soybean thrips (Nv), and undetermined thrips larvae in unsprayed nectarines, 1987.

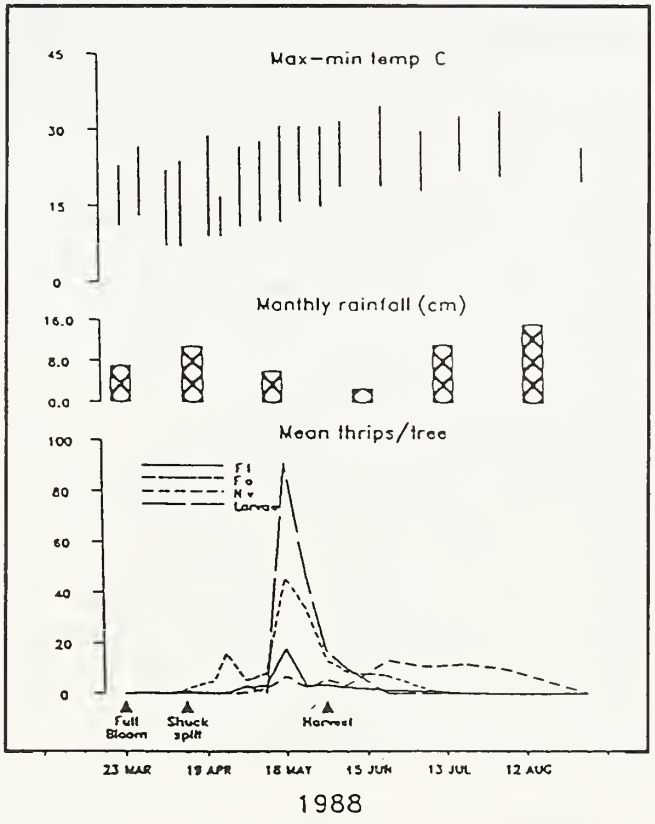


Figure 3. Seasonal distribution of adults of the flower thrips (Ft), the western flower thrips (Fo), the soybean thrips (Nv), and undetermined thrips larvae in unsprayed nectarines, 1988.

EVALUATION OF ALTERNATE ROW-MIDDLE SPRAY APPLICATIONS OF PESTICIDES ON PEACHES FOR CONTROL OF INSECT PESTS AND DISEASES

J.R. McVay[1], T.B. McInnes[2] and
J.A. Pitts[3]

INTRODUCTION

Traditionally, the application of pesticides to orchard crops, including peaches, involves the use of air-blast sprayers traveling each row middle and applying the finished spray to both sides of each tree row. Recently, there has been an increased degree of interest in applying the spray to only one side of the tree row and gaining adequate pest control by forcing the spray material through the tree canopy. Crops such as peaches and apples are produced on relatively small trees and should be good candidates for this type of application. The air-blast type of sprayer produces a plume of pesticide-laden air which is forced into the tree canopy in an effort at replacement of the air already there. If alternate row spraying can be proven effective, substantial savings in time and energy can be obtained when applying any of the several pesticide applications necessary each year for fruit production in Alabama. A trial was designed to evaluate this technique in a planting of standard sized (mature) peach trees.

METHODS AND MATERIALS

The trial was conducted at the Chilton Area Horticultural Substation of the Alabama Agricultural Experiment Station during the 1990 and 1991 production years. The experimental design was a randomized complete block consisting of four replications per treatment with six Topaz variety peach trees planted on twenty foot centers per replication. An orchard air-blast sprayer was calibrated and used to make the pesticide applications. Fungicide and insecticide treatments were applied according to the current Commercial Peach Spray Guide, AL Cooperative Extension Circular ANR-8. All treatments received the same materials except for an additional application of Bravo 720 (4 1/8 pt./A) after shuck split in treatment two (see below). Sprays were applied on a standard schedule from 13 March until 13 June.

Treatments were:

1. Standard method of pesticide application; fungicides and insecticides applied to both sides of each tree row for the entire season (200 gal/A; 9 applications).

2. Standard method of pesticide application; fungicides and insecticides applied as in Treatment 1 plus the addition of the post shuck-split Bravo application.

3. Alternate Row Middle (ARM) method of pesticide application for the entire season. ARM involved the application of sprays to one side of each tree row (100 gal/A; 9 applications). The side treated was also alternated with each application.

4. ARM method of application for all sprays except "preharvest sprays" which were applied as in treatment 1 (100 gal/A for 7 applications and 200 gal/A for 2 preharvest sprays).

5. Standard method of application for all sprays except the "cover sprays" which were applied by the ARM method (100 gal/A for 5 cover sprays and 200 gal/A for 2 early and 2 preharvest sprays).

6. Nonsprayed control.

Insect damage ratings were made on 25 fruit from the center tree of each plot at thinning and at the midpoint between thinning and harvest. Plots were harvested on 14 June and a 50 fruit

[1]Extension Entomologist and Associate Professor, Department of Entomology, Auburn University, AL 36849

[2]Former Extension Plant Pathologist, Auburn University, AL 36849

[3]Superintendent, Chilton Area Horticultural Substation, Alabama Agricultural Experiment Station, Clanton, AL 35045

subsample was rated for insect damage. Insect damage inspected for included the plum curculio and all catfacing damage.

Disease incidence of brown rot and Rhizopus rot was rated on the 50 fruit subsamples taken at harvest and again on 25 fruit subsamples that were held for 4 days post harvest. Data from all rating periods were combined and analyzed by a test for Least Significant Differences.

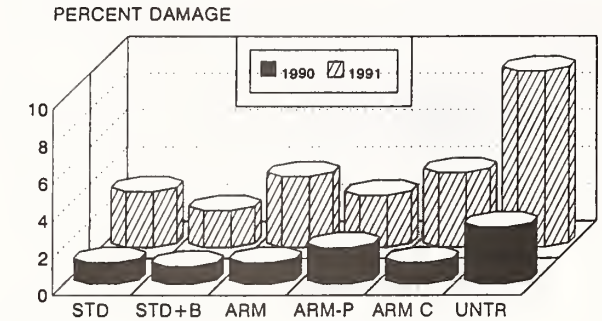
RESULTS

Results of the ratings for incidence of insect damage and disease are presented in Figs. 1-4. All are expressed as percent damaged or infected. In 1990, no significant differences were detected among treatments when ratings were made for plum curculio damage, brown rot or Rhizopus rot (Figs. 1, 3 and 4). The incidence of catfacing damage in Treatments 2 and 4 was significantly less (LSD, $P=0.05$) than in the untreated (Fig. 2). No other statistical differences were detected. Insect populations were considered light during the 1990 growing season and weather conditions were not overly conducive to disease development.

In 1991, among values analyzed for incidence of insect damage, all treatments produced significantly better control than the untreated and were not significantly different from each other for either catfacing injury or curculio damage (Figs. 1, 2). There were no significant differences among any treatments, including the control, for incidence of either brown rot or Rhizopus rot (Figs. 3, 4). Insect infestations were considered moderate in 1992 during the time of the study and weather conditions were fairly conducive to disease development.

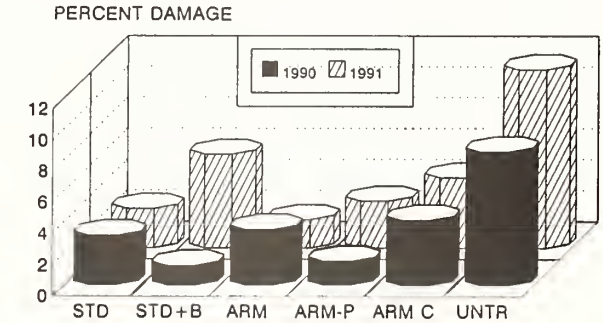
CONCLUSIONS

After the second year of this trial it appears that the use of the ARM method of pesticide application does not reduce the control of insect or disease injury when compared to standard application methods. Commercial adoption of this method should result in substantial savings to producers in both time and finances invested.



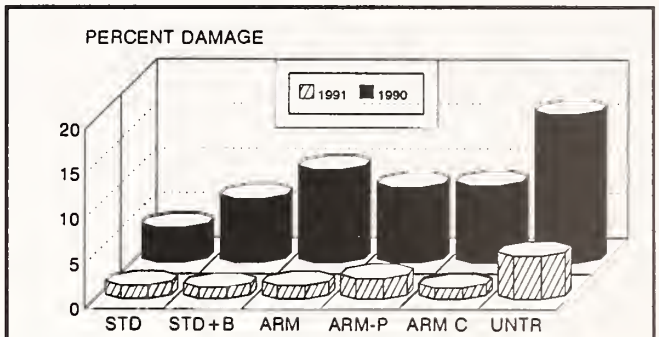
1991	3	2	3.8	2.8	4	9.5
1990	1.2	1	1.2	2	1.2	3.1

Figure 1. Percent damage by the plum curculio in alternate-row spray trial, 1990-91. (STD=standard pesticide application; STD + B=Standard + Bravo; ARM = alternate row middle; ARM - P=ARM minus preharvest sprays; ARM C=ARM except cover sprays; UNTR=nonsprayed control)



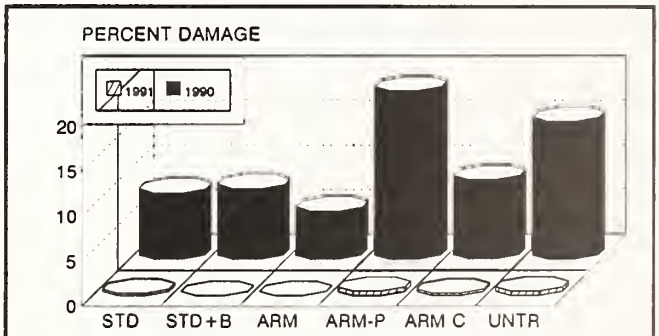
1991	2.5	6	1.8	3	4.5	11.5
1990	3.2	1.3	3.6	1.6	4.2	8.6

Figure 2. Percent damage by catfacing insects in alternate-row spray trial, 1990-91. (STD=standard pesticide application; STD + B=Standard + Bravo; ARM=alternate row middle; ARM - P=ARM minus preharvest sprays; ARM C=ARM except cover sprays; UNTR=nonsprayed control)



1990	4	7.2	10.5	8.5	8.7	16.7
1991	1.5	1.3	1.5	2.3	1.3	4.8

Figure 3. Incidence of brown rot in alternate-row spray trial, 1990-91. (STD=standard pesticide application; STD + B=Standard and Bravo; ARM=alternate row middle; ARM - P=ARM minus preharvest sprays; ARM C=ARM except cover sprays; UNTR=nonsprayed control)



1990	7.5	8	5.5	19	9	15.5
1991	0.3	0	0	0.5	0.3	0.5

Figure 4. Incidence of Rhizopus rot in alternate-row spray trial, 1990-91. (STD=standard pesticide application; STD + B=Standard + Bravo; ARM=alternate row middle; ARM - P=ARM minus preharvest sprays; ARM C=ARM except cover sprays; UNTR=nonsprayed control)

ALTERNATE-ROW-MIDDLE INSECTICIDE APPLICATION IN SOUTHEASTERN PEACHES

D.L. Horton[1], F.F. Hendrix[1], S. Chang[1], C.E. Yonce[2] and J.A. Payne[2]

ABSTRACT

Alternate-row-middle (ARM) pesticide application was examined on peaches. ARM appeared to offer potential advantages in flexibility and rapid response to pest management needs.

INTRODUCTION

Stone fruit experience heavy insect and disease pressures in the warm, humid southeastern U.S. Pest management decisions have been limited to adjusting the frequency of preventative sprays. Adoption of more refined pest management strategies are limited by inadequate understanding of pest biology, the lack of commercially acceptable sampling techniques, and by the logistical constraint of sprayer to acreage sprayed ratios that sometimes require almost continuous spraying to maintain adequate pesticide coverage.

Orchard pesticide applications, regardless of crop, are made almost exclusively with airblast sprayers (Hickey 1984). Airblast spraying is prone to drift. **Complete** spraying applies pesticide to both sides of each tree-row during each spray application. This is the standard practice in most orchard pesticide applications. **Alternate-row-middle** (ARM) spraying takes advantage of drift onto adjacent tree-rows. Alternate sides of trees, are sprayed, generally at shorter treatment intervals. This system of orchard spraying was developed in New York to provide rapid, and economical application of short residual fungicides that must be frequently applied for control of apple scab. ARM spraying is widely used by apple growers in Pennsylvania, where it offers considerable advantages in managing European red mite populations (Asquith and Hull, 1979; Hull et al., 1983). It is particularly well suited to pest management systems that make frequent use of short residual pesticides (Hickey, 1984). This study compared season-long ARM spraying to complete spraying in early-season and mid-season Southeastern peach cultivars.

[1]University of Georgia, Athens, GA 30602

[2]USDA-ARS, Southeastern Fruit and Tree Nut Research Laboratory, Byron, GA 31008

METHODS AND MATERIALS

Experiments were conducted at the USDA-ARS's Southeastern Fruit and Tree Nut Research Laboratory, in Byron, GA. The test orchard consisted of adjoining blocks of 'Sunbrite', an early-season cultivar, and 'Harvester', a mid-season selection. The ARM block was bordered on the south side by 120 'Majestic' peaches, a late-season cultivar, and ca. 60 plum trees. These neighboring trees were left unsprayed in an effort to encourage heavy pest pressure.

A randomized complete block design, with blocking by cultivar, and two treatments was used in both years.

In 1988 and 1989 the efficacy of similar season-long spray regimes were compared. The same pesticides and rates were used for complete and ARM sprays, but the effective dosage applied to ARM trees in each individual application was reduced by one half each time. However, ARM treatments were treated an additional time between each complete spray application. Total pesticide application to the two treatments was essentially identical. Complete spray treatments, in which both sides of each tree-row were sprayed every time a pesticide application was called for in the Georgia Peach Spray Guide (Bertrand et al., 1988; Bertrand et al., 1989).

An FMC LV500 sprayer was used in 1988. It was calibrated to apply 938 L/ha (100 gal/A) when run at 5.6 km/hr (3.5 mph). Air displacement was ca. 710,648 L/min (25,000 cu ft/min) (Bassett, pers. comm.). A Cropliner 820 PTO-powered sprayer calibrated to apply 582 L/ha (62 gal/A) when run at 3.5 km/ha (2.2 mph) was used in 1989. Estimated air displacement was 1,080,184 L/min (38,000 cu ft/min) (Perry, pers. comm.).

Complete vs. ARM spray trials were evaluated on the basis of detailed examination of injury to harvested fruit. Minor insect injury that normally would have been ignored on a commercial packing line was noted (Davidson, pers. comm.). In 1988 and 1989, 3,000 fruit from each cultivar were examined for insect injury.

RESULTS

Comparison of complete vs. ARM spray application to peaches demonstrated that, with the exceptions of thrips control, ARM spray application provided insect control equivalent to that provided by complete spray application. The climatic conditions and pest pressure varied considerably between the two years; 1988 was a dry year with heavy insect pressure, while 1989 was a very wet season with minimal pest insect pressure. Comparison of plant bug and stink bug control revealed no meaningful difference between the complete and ARM treatments. Plum curculio data showed inconsistency. In the face of very heavy curculio pressure, both complete and ARM treatments experienced marginal control. These lapses seem more attributable to the inconsistency of plum curculio injury within a block. Thrips injury was particularly apparent in 1988. Thrips injury to stonefruit in the Southeast has been associated with incomplete spray coverage. Thrips are not serious pests of peaches in the Southeast (Yonce et al., 1990).

DISCUSSION

Our data supports the judicious use of ARM spraying as an IPM tool. Grower utilization of ARM spraying further supports this opinion. In 1992 several middle Georgia growers successfully used ARM spraying to frequently apply sulfur, while making less frequent applications of long residual insecticides.

LITERATURE CITED

Asquith, D. and L.A. Hull. 1979. Integrated pest management systems in Pennsylvania apple orchards, Pp. 203-222. In: D.J. Boethel and R.D. Eikenberry (eds.) Pest Management Programs for Deciduous Tree Fruits and Nuts. Plenum Press, New York. 256 Pp.

Bertrand, P.F., D.L. Horton, HC Ellis, G.K. Krewer and S.C. Myers. 1988. Georgia peach spray guide. Univ. of GA, Coop. Ext. Serv., Misc. Pub. 46.

Bertrand, P.F., D.L. Horton, HC Ellis, G.K. Krewer and S.C. Myers. 1989. Georgia peach spray guide. Univ. of GA, Coop. Ext. Serv., Misc. Pub. 46.

Hickey, K.D. 1984. Proceedings of the eastern conference on the application of agricultural chemicals to tree fruit with ground equipment. Harpers Ferry, WV. Pp. 1-8.

Hull, L.A., K.D. Hickey and K.W. Kanour. 1983. Pesticide usage patterns and associated pest damage in commercial apple orchards of Pennsylvania. J. Econ. Entomol. 76:577-583.

Yonce, C.E., J.A. Payne, R.J. Beshear and D.L. Horton. 1990. Thrips (Thysanoptera: Thripidae) associated with unsprayed and sprayed peaches in Georgia. J. Econ. Entomol. 83:511-518.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1994 300-118/00025